AD A094172

USAAEFA PROJECT NO. 78-09

(12)

LEVEL II

PRELIMINARY AIRWORTHINESS EVALUATION OH-58C HELICOPTER WITH A MAST MOUNTED SIGHT

FINAL REPORT

JOHN A. BISHOP
CW4, AV
US ARMY
PROJECT OFFICER/PILOT

TOM P. BENSON
PROJECT ENGINEER

MARVIN L. HANKS
CPT, CE
US ARMY
PROJECT PILOT

ARTHUR M. ARRIGO
PROJECT ENGINEER

MAY 1980

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UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: USAAEFA PROJECT NO. 78-09
2. GOVT ACCESSION NO.: AD-A094172
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): PRELIMINARY AIRWORTHINESS EVALUATION OH-58C HELICOPTER CONFIGURED WITH A MAST MOUNTED SIGHT
5. TYPE OF REPORT & PERIOD COVERED: FINAL REPORT OCTOBER 1980
6. PERFORMING ORG. REPORT NUMBER: USAAEFA-78-09
7. AUTHOR(s): JOHN A. BISHOP, CW4; MARVIN L. HANKS, CPT; TOM P. BENSON; ARTHUR M. ARRIGO
8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US ARMY AVIATION ENGINEERING FLIGHT ACTIVITY EDWARDS AFB, CALIFORNIA 93523
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: EKOPWOO1EKEC
11. CONTROLLING OFFICE NAME AND ADDRESS: US ARMY AVIATION ENGINEERING FLIGHT ACTIVITY EDWARDS AFB, CALIFORNIA 93523
12. REPORT DATE: MAY 1980
13. NUMBER OF PAGES: 74
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

PAE	Model 570B SCAS
Dummy mast nounted sight	Rockwell International Sight
Selectine Reassembly	Pitch lagged rate term

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The United States Army Aviation Engineering Flight Activity conducted a preliminary airworthiness evaluation of the OH-58C helicopter with a mast mounted sight and Bell Helicopter Textron Model 570B three-axis stability and control augmentation system. The evaluation was completed in two phases at the Bell Helicopter Engineering Flight Research Center, Arlington, Texas (elevation 630 ft). Phase 1 consisted of an evaluation of a dummy mast mounted sight installed on an instrumented helicopter. This phase was conducted between 15 and 30 October 1980 and 12 flights were flown for a total of 9.7 productive hours. Phase 2 consisted of a qualitative assessment of the handling qualities of the OH-58C configured with the operational Rockwell International sight. This phase was completed on

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

30 November 1980 in two flights for 1.5 productive test flight hours. The overall evaluation indicated that the OH-58C handling qualities with installed mast mounted sight and three-axis SCAS were satisfactory within the flight envelope tested. No problems were noted that will prevent future operational testing of the system. The addition of a three-axis SCAS significantly improved the OH-58C handling qualities, particularly in low speed flight, and is an enhancing characteristic. Four deficiencies were noted: (1) single electrical power interruptions or SCAS component failures will result in simultaneous three-axis control inputs; (2) the unguarded copilot collective pitch bellcrank (collective removed) could result in control jamming; (3) the divergent long period in high rates of climb at 50 to 60 knots; (4) the low frequency (1/rev and 2/rev) vibrations noted in forward, right sideward, and rearward flight that would prevent the sight operator from utilizing the sight controls efficiently. The vibrations noted in Phase 1 were significantly reduced by the selective assembly of close tolerance mast and sight components when the operational sight was installed. The only vibrations noted during Phase 2 were in right sideward and rearward flight and the deficiency noted above was downgraded to a shortcoming. The divergent long period oscillation noted in high rates of climb was eliminated prior to Phase 2 testing by the addition of a lagged rate term within the pitch logic of the SCAS. The possibility of three-axis control inputs due to a single electrical power interruption and the unguarded copilot collective bellcrank were not corrected during this evluation and remain deficiencies that should be corrected prior to operational testing. A total of four other shortcomings were noted that were attributable to the SCAS or mast mounted sight installations.

DEPARTMENT OF THE ARMY

HQ, US ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND
4300 GOODFELLOW BOULEVARD, ST. LOUIS, MO 63120

JAN 5 1981

DRDAV-D

SUBJECT: Directorate for Development and Qualification Position on the Final Report of USAAEFA Project No. 78-09, Preliminary Airworthiness Evaluation, OH-58C Helicopter Configured with a Mast Mounted Sight

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1. The purpose of this letter is to establish the Directorate for Development and Qualification position on the subject report. This evaluation was conducted in two phases, to assess the handling qualities of the OH-58C helicopter with a mast mounted sight (MMS) and a three axis stability and control augmentation system (SCAS). Phase 1 consisted of testing with an instrumented dummy MMS and instrumented OH-58C to obtain quantitative handling qualities data. Phase 2 consisted of a qualitative handling qualities evaluation of the OH-58C with an operational MMS. A limited operational envelope for user tests was released for the OH-58C with an operational MMS and three axis SCAS. It is important to note that the MMS was a prototype installation while the three axis SCAS was FAA certified for the commercial Jet Ranger helicopter and not fully qualified on the OH-58C.

2. This Directorate agrees with the report findings, conclusions, and recommendations with some exceptions as indicated below. Since this report presents the results of a Preliminary Airworthiness Evaluation of an item intended only for feasibility testing, the use of Deficiencies and Shortcomings relating to type classification of hardware intended for operational use is not really important; however, the problems defined should and will be considered. The following comments are provided relative to the conclusions and are directed to the report paragraph as indicated.

a. Paragraph 48a. The possibility of uncommanded three-axis control inputs as a result of a single SCAS switch actuation or failure is not considered a deficiency. Uncommanded centering inputs will result in aircraft response only if an offset exists in the first place (i.e., a body rate is present). If this is the case, then it is probably the result of the pilot maneuvering the helicopter which implies he is on the controls and will react to eliminate unwanted helicopter responses. The configuration was, therefore, not withheld from further testing.

b. Paragraph 48b. With the copilot's collective removed, the configuration is the same as for a standard OH-58C, which is not new. There has never been any field experience of collective control jamming with the copilot collective pitch lever bell crank unguarded.

c. Paragraph 48c. Because of the divergent long period oscillation noted in high rates of climb, the OH-58C has been limited to 1000 fpm climb rate except in an emergency.

d. Paragraph 50. The selective assembly of the MMS components indicates that any fielded system will require close tolerance fits and represents a manufacturing problem. However, this is not considered a shortcoming.

e. Paragraph 51a. Since this evaluation was a feasibility test, which proved successful, a limited flight path normal acceleration envelope is considered adequate for further user testing; however, operational use of the configuration as a scout helicopter would require significantly greater maneuvering capability.

f. Paragraph 51b. The design and location of the SCAS power switch was unique to the test OH-58C. For any follow on development effort, the switch would be redesigned as well as relocated.

g. Paragraphs 51c and 51d. The light directional control breakout (plus friction) and the lack of a directional control force gradient system are shortcomings common to the standard; however, there is no current effort to correct these shortcomings.

h. Paragraph 51c. The airframe vibrations noted in right sideward and rearward flight is apparently associated with the MMS. The impact of the vibrations on the operational utilization on the MMS is undetermined; however, it should not significantly impact the user evaluation. Any future development effort would consider the vibration characteristics.

i. Paragraphs 52a and 52b. While two specification requirements for the flight control system were not met, they would be waived since the areas of noncompliance are acceptable.

j. Paragraph 53. For the reasons stated previously, the test OH-58C was released to the user for continued feasibility testing.

k. Paragraph 54. It is not warranted that existing shortcomings be corrected this time since only feasibility tests are being conducted.

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l. Paragraphs 55 and 56. The normal acceleration envelope is considered adequate for user tests. A caution was incorporated in the Airworthiness Release issued to the user restricting the load factor envelope to +0.5g to +1.5g for all gross weight and cg conditions.

m. Paragraphs 57 and 58. Further SCAS related testing will be accomplished as recommended should the OH-58C with the MMS and SCAS installed be further developed.

n. Paragraph 59. For the reasons stated in paragraph 2a, we do not conduct additional SCAS flight testing prior to the release of the test helicopter for user tests. However, cautions relative to hardover characteristics were included in the Airworthiness Release to the user so that he would be aware of helicopter responses to SCAS hardovers.

FOR THE COMMANDER:

CHARLES C. CRAWFORD, JR.
Director of Development
and Qualification

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INTRODUCTION

BACKGROUND

1. Bell Helicopter Textron (BHT) conducted a feasibility demonstration of an OH-58C helicopter with a Mast Mounted Sight (MMS) and a three-axis Stability and Control Augmentation System (SCAS) installed. The feasibility demonstration by BHT initially utilized a dummy sight of approximately the same size and weight characteristics of the operational Rockwell International (Rockwell) sight to be installed for future US Army operational testing. The US Army Aviation Research and Development Command (AVRADCOM) tasked the US Army Aviation Engineering Flight Activity (USAAEFA) to conduct a Preliminary Airworthiness Evaluation (PAE) of the OH-58C helicopter with an installed dummy MMS and a three-axis SCAS (ref 1, app A). Additionally, a qualitative assessment of the handling qualities was required when BHT removed the dummy MMS and test instrumentation and installed the operational MMS and its associated instrumentation package (ref 2).

TEST OBJECTIVES

2. The objectives of this test were to:

a. Determine the changes in handling qualities of the OH-58C helicopter as a result of the installation of an MMS and a three-axis SCAS.

b. Qualitatively evaluate any changes in handling qualities between the dummy MMS and the operational Rockwell sight installation.

DESCRIPTION

3. The OH-58C helicopter is a modification of the OH-58A built by BHT, Fort Worth, Texas. The OH-58C has a single two-bladed, semi-rigid, teetering-type main rotor and a single two-bladed, delta-hinged, semi-rigid, teetering- type tail rotor. The design gross weight of the helicopter is 3200 pounds. The aircraft is powered by an Allison T63A-720 engine with an uninstalled intermediate rating (30 minutes) of 420 shaft horsepower (shp) under sea level standard conditions. The helicopter main rotor transmission has a five-minute rating of 317 shp and a continuous rating of 270 shp. The test helicopter, serial number 69-16214, was equipped with dual hydromechanically-boosted flight controls in all three axes. The vulnerability-reduction directional-control system was removed from the test helicopter to accomodate the installation of the hydraulic boost required for the three-axis SCAS. The left seat controls were removed to allow for the installation of the Rockwell sight-operator controls for the operational MMS testing. A detailed description of the basic helicopter is contained in the operator's manual (ref 3).

4. The dummy MMS used in the instrumented test phase of the PAE consisted of a vibration isolated nonrotating structure that was representative of the operational Rockwell sight in shape, size, and weight (photos 1 and 2, app B). The sight extended two feet above the main rotor mast and was secured to the main transmission by the use of a standpipe that extended through the mast to the base of the transmission. The dummy MMS installation weighed approximately 118 pounds including test instrumentation (table 2, app B). A detailed description of the

dummy sight installation is contained in appendix B.

5. The Rockwell MMS installation consisted of the MMS standpipe, copilot seat operator controls, rear seat observer console, instrumentation, and audio and video tape recording systems. The entire system weighed 260 pounds with the mast mounted components weighing approximately 118 lbs. The external components of the system closely approximated the dummy installation in shape and size (photos 3 and 4). A detailed description of the Rockwell sight is contained in appendix B.

6. The test helicopter was equipped with a BHT model 570B three-axis SCAS which had previously been type certified by the Federal Aviation Administration (FAA) on a BHT 206 helicopter. The SCAS consisted of a control panel, a sensor amplifier, three electrohydraulic actuators, and three control motion transducers. The SCAS was a limited authority three-axis, rate-referenced stability augmentation system. The system incorporated control position transducers that distinguished between pilot control inputs and external airframe disturbances to allow a pilot fly-through capability. A detailed description of the SCAS is contained in appendix B.

TEST SCOPE

7. The USAAEFA evaluation was conducted in two phases at the BHT Engineering Flight Research Center, Arlington, Texas. Phase 1 was completed from 15 to 30 October 1979 and consisted of an evaluation of the dummy MMS installation. Phase 1 of the PAE required 12 flights for a total of 9.1 productive hours. Phase 2 of the PAE consisted of a qualitative evaluation of the operational Rockwell MMS installation and was conducted on 30 November 1979. Two flights were required and a total of 1.5 productive test hours were flown. Flight limitations contained in the operator's manual (ref 3, app A), and the airworthiness release (refs 4 and 5) were observed. The test conditions are presented in table 1. Handling qualities were evaluated with respect to the applicable requirements of MIL-H-8501A (ref 6).

TEST METHODOLOGY

8. Flight test data for Phase 1 of the PAE were recorded on magnetic tape utilizing an on-board BHT instrumentation package (app C). Telemetry was utilized for monitoring critical component parameters during all Phase 1 testing. Test data for Phase 2 of the PAE were hand recorded utilizing standard cockpit instrumentation. The test techniques used are described in reference 7, appendix A and in appendix D. The handling qualities were evaluated in accordance with the Handling Qualities Rating Scale (HQRS) contained in figure 1, appendix D.

Table 1. Flight Test Conditions[1]

Test	Average Density Altitude (ft)	Average Gross Weight (lb)	Center of Gravity Location (FS)[2]	Rotor Speed (RPM)	Calibrated Airspeed (kt)[3]	Flight Mode
Control positions in trimmed forward flight	2720 2780	3180 3140	109.9 109.8	355 349	34 to 96 33 to 96	Level Level
Static longitudinal stability (collective fixed)	3680 4000	3200 3160	109.6 109.5	354 354	35 to 84 58 to 100	Level Level
Static lateral-directional stability	3600	3200	109.5	354	60 and 79	Level
Maneuvering stability	5180	3100	109.5	354	60 and 79	Level
Dynamic stability	2120 to 4040	2960 to 3120	109.7 to 109.9	354	36 to 84	Level and climbs
Controllability	540 to 5120	3080 to 3140	109.4 to 109.7	354	0 to 86	Hover and level
Low speed flight	860 to 2180	3080 to 3220	109.2 to 109.6	354	35 Lt to 35 Rt 30 rearward to 42 forward	Simulated hovering in winds
Simulated sudden engine failures	3540 to 4340	2920 to 3020	109.7 to 109.8	354	59 and 60	Level and climb
SCAS failures	1500 and 3820	2920 and 3020	109.7 and 109.8	354	59 and 60	Level

[1] Configuration: clean, doors-on, mast mounted sight installed.
[2] All cg locations mid.
[3] Low speed flight airspeed measured in knots true airspeed.

RESULTS AND DISCUSSION

GENERAL

9. A PAE evaluation was conducted to determine the changes in handling qualities of the OH-58C helicopter due to the installation of a MMS and a three-axis SCAS. The evaluation was completed in two phases. Phase 1 consisted of an evaluation of a dummy MMS installation using an instrumented helicopter. Phase 2 consisted of an evaluation of the operational Rockwell MMS using an uninstrumented helicopter.

10. The overall evaluation of the OH-58C helicopter equipped with an MMS and three-axis SCAS indicates the handling qualities are satisfactory within the flight envelope tested (refs 4 and 5, app A). No problems were noted that will prevent further operational testing of the MMS concept. The addition of a three-axis SCAS significantly improves the helicopter's handling qualities and decreases the pilot workload, especially in the low speed flight regime where the MMS will be most utilized. The addition of a three-axis SCAS is an enhancing characteristic. However, limited fault analysis and ground testing of the SCAS indicated that single component failures may result in simultaneous three-axis control inputs. Further evaluation of the failure modes and correction of the SCAS problems is required prior to operational use on the OH-58C.

11. The following 4 deficiencies were noted in Phase 1 of the PAE: single SCAS component failures that may result in significant simultaneous three-axis control inputs, the unguarded copilot collective pitch lever bell crank, the divergent long period of the helicopter in rates of climb greater than 1000 feet per minute (fpm) at 50 to 60 knots calibrated airspeed (KCAS), and the low frequency airframe vibrations in forward flight, right sideward flight, and rearward flight. A total of 5 other shortcomings were noted.

12. The lateral control rigging was found to be out of limits (app B) prior to USAAEFA testing. This resulted in an approximate one degree misalignment between the vertical axis of the main rotor mast and the swashplate. Phase 1 was completed with this out-of-rig condition as it was determined that it would have minimal effect on handling qualities and comparability with previous contractor MMS flight test data (ref 8) carried a higher priority. The rigging error was corrected prior to the start of Phase 2 and no changes in handling qualities could be attributed to the rigging change.

13. The following 2 deficiencies noted in Phase 1 of the PAE still existed in Phase 2: the possibility of a simultaneous three-axis control input as the result of a single SCAS component failure and the unguarded copilot collective pitch bell crank. The divergent long period characteristic in climbs noted in Phase 1 was corrected by the addition of a lag rate term within the SCAS logic circuits and the long period characteristic within the scope of this test was then satisfactory. The excessive vibrations noted in Phase 1 were significantly reduced by selective reassembly of close tolerance mast and MMS components when the operational MMS was installed. The only objectionable vibrations noted in Phase 2 were one per revolution (1/rev) and 2/rev vibrations in right sideward and rearward flight which constituted a shortcoming. The five shortcomings noted during Phase 1 still existed.

HANDLING QUALITIES

Control System Characteristics

14. The control system characteristics were evaluated with rotors static, SCAS ON, and electrical and hydraulic power applied to the helicopter. Control forces were measured using a hand-held force gauge and were qualitatively verified in flight. The longitudinal and lateral cyclic control system characteristics were unchanged from the standard OH-58C helicopter (ref 9, app A). The large trim control displacement bands were similar to those of the standard OH-58C and remain a shortcoming. The directional control system characteristics were significantly changed from the standard OH-58C due to the installation of a hydraulic boost actuator required for the three-axis SCAS. During Phase 1 of the PAE the directional control system characteristics were documented and are presented in figure 1, appendix E. The directional control breakout (including friction) was approximately 1/2 pound for right pedal and approximately 1 1/2 pounds for left pedal. No force gradient or trim system was incorporated in the directional axis. The light breakout (plus friction) forces and lack of a force gradient system contributed to directional overcontrol problems experienced by the pilot and are further discussed in paragraph 28. The lack of a force gradient system failed to meet the requirements of paragraph 3.3.10 of MIL-H-8501A in that positive self-centering was not present.

15. During the contractor installation of the Rockwell MMS, the directional control system components were adjusted to increase the breakout (including friction) of the pedals. The directional control system characteristics were rechecked by USAAEFA prior to the conclusion of Phase 2 of the PAE and the results are presented in figure 2. The breakout (including friction) was increased to approximately 6 pounds for right pedal forward application and to approximately 5.5 pounds for left pedal applications. The increased breakout (plus friction) force decreased the tendency of the pilot to overcontrol the aircraft directionally, but is still a shortcoming (para 28).

16. The control system characteristics were satisfactory as documented in Phase 2 of the PAE except the light directional control breakout (plus friction) forces and the lack of a directional control force gradient system, which are shortcomings. The directional control system mechanical characteristics initially failed to meet para 3.3.12 in that the breakout (plus friction) force for left or right pedal displacements (0.5 to 1.5 lb) was less than that required by MIL-H-8501A. During Phase 2 testing, the directional control breakout (plus friction) was adjusted and did meet the above requirement.

Control Positions in Trimmed Forward Flight

17. The control positions in trimmed level forward flight were evaluated at the conditions listed in table 1. The test results are presented in figure 3, appendix F. The variation of longitudinal control position was positive in that increasing forward control was required for increasing airspeed. The gradient of longitudinal control position to airspeed was essentially neutral from 33 to 40 KCAS but no adverse handling qualities were attributable to this characteristic. The lateral and directional control displacements required with increasing airspeed were minimal and control margins at all conditions tested were adequate. No objectionable characteristics were noted in transitions from level flight to climbs or descents. The level flight trim control position characteristics of the OH-58C with MMS and SCAS were similar to the standard helicopter and are satisfactory.

Static Longitudinal Stability

18. The static longitudinal stability characteristics of the OH-58C helicopter configured with the MMS were evaluated at the conditions listed in table 1 using the flight test techniques described in appendix D. The static longitudinal stability data are presented in figure 4, appendix E. Collective fixed trim airspeeds of 62 and 82 KCAS were used with SCAS ON. The static longitudinal stability was weak but positive at both airspeeds tested. Quantitative results obtained in Phase 1 as well as qualitative results observed in Phase 2 indicate no change in the static longitudinal stability characteristics of the OH-58C aircraft configured with the MMS as compared to basic OH-58C characteristics described in reference 9, appendix A.

Static Lateral-Directional Stability

19. The static lateral-directional flight characteristics of the OH-58C helicopter configured with the MMS were qualitatively evaluated using the steady heading sideslip method discussed in appendix D at the conditions listed in table 1. The qualitative results indicated that the positive directional stability, positive dihedral effect, and side force characteristics were unchanged from the basic OH-58C for both MMS configurations (ref 9, app A). The static lateral-directional stability characteristics of the OH-58C helicopter configured with the MMS and three-axis SCAS are satisfactory.

Maneuvering Stability

20. The SCAS ON maneuvering stability characteristics of the OH-58C MMS helicopter were evaluated in left and right steady turns, pull-ups, and push-overs using the test techniques described in appendix D at the conditions listed in table 1. Data gathered during Phase 1 testing is presented in figure 5, appendix E. The maneuvering stability characteristics determined during Phase 1 and qualitatively confirmed during Phase 2 for the OH-58C MMS helicopter with three-axis SCAS were unchanged from those noted for the basic OH-58C aircraft (ref 9, app A) and are satisfactory. The AVRADCOM issued airworthiness releases (refs 4 and 5) established a +0.6 to 1.4 g flight path normal acceleration limitation for this test program. Even with sensitive g meter instrumentation, normal acceleration limitations were exceeded by 0.08 g in turning flight at 60 knots indicated airspeed (KIAS) and by 0.04 g at 79 KIAS with approximately two-inch aft stick displacements. Routine light observation helicopter tactics involve similar mission maneuvers that may occasionally be more severe than those documented during these tests. The limited flight path normal acceleration envelope developed for the OH-58C MMS aircraft is easily exceeded and a shortcoming. Further tests should be conducted to expand the normal acceleration envelope prior to system operational use. As an interim procedure the following caution should be placed in the operational testing airworthiness release.

CAUTION

The +0.6 to 1.4 g flight path normal acceleration limitations can easily be exceeded during mission maneuvers.

Dynamic Stability

21. The long term longitudinal dynamic stability characteristics of the OH-58C helicopter with MMS and SCAS ON and OFF were evaluated at the conditions listed in table 1 and using the test techniques described in appendix D. Recorded data (SCAS OFF) is presented in figures 6 through 8, appendix E. With the SCAS OFF the longitudinal long term oscillation was damped in level flight at both airspeeds tested. The long term oscillation with SCAS OFF became oscillatory divergent at moderate climb rates (800 fpm) and 59 KCAS (fig 8). High power climbs (1500 fpm) at 59 KCAS exhibited similar divergent long term oscillation characteristics. The SCAS OFF longitudinal long term characteristics were essentially unchanged from the basic OH-58C helicopter. The previously noted deficiency, divergent long term at high climb rates, (ref 8, app A) for the basic OH-58C helicopter is also present with the MMS configuration.

22. Additional tests were conducted to evaluate the longitudinal long term characteristics of the OH-58C helicopter with MMS and SCAS ON. The SCAS ON long term longitudinal oscillations were essentially neutrally damped at the level flight airspeeds tested (figs 9 and 10, app E). The divergent tendency of the long term oscillation during climb at 59 KCAS was aggravated with SCAS ON (fig 11 and 12). The long term characteristics noted with SCAS ON, as compared to SCAS OFF, demonstrated that the addition of a SCAS degraded the stability of the long term mode.

23. Prior to the Phase 2 evaluation the SCAS was modified by the incorporation of a lagged pitch rate term (app B). During Phase 2, forward flight climbs were conducted at 59 KCAS at moderate (700 FPM) and high (1500 FPM) rates of climb. Essentially "hands off" flight was attainable with the modified SCAS. Small airspeed deviations were introduced, and no tendency for pitch divergence was noted. Further tests should be conducted on the OH-58C helicopter equipped with a three-axis SCAS incorporating a lagged pitch rate term to fully evaluate the apparent improvement of the longitudinal long-term dynamic stability at high-power climb conditions and determine any affects on handling qualities throughout the entire flight envelope.

24. The dynamic lateral-directional characteristics of the OH-58C helicopter configured with MMS and three-axis SCAS were evaluated using the procedures described in appendix D and at the conditions listed in table 1. The SCAS OFF lateral-directional characteristics observed were unchanged from those noted in the basic OH-58C and are depicted in figure 13, appendix E. No differences were noted between the dummy MMS and the Rockwell sight configurations during these tests. The easily excited, lightly-damped, lateral-directional gust response of the OH-58C helicopter (SCAS OFF) equipped with MMS continues to be a shortcoming.

25. The dynamic lateral-directional characteristics with SCAS ON were essentially identical for both MMS configurations. The SCAS ON oscillations, due to directional or lateral control doublets or natural gust response, were heavily damped (fig 14) when compared to the standard OH-58C. The improved lateral-directional oscillation characteristics with SCAS ON greatly decrease the pilot workload required to maintain precise bank angles and/or heading control. The dynamic lateral-directional characteristics of the OH-58C MMS helicopter equipped with three-axis SCAS are satisfactory.

Controllability

26. Hovering and forward flight longitudinal and lateral controllability tests were conducted at the conditions listed in table 1 using test techniques described in appendix D. Data were recorded SCAS ON and SCAS OFF for comparison. SCAS OFF hover longitudinal and lateral controllability characteristics are shown in figures 15 and 16, appendix E. No changes in longitudinal or lateral axis controllability characteristics were noted for the MMS configuration with SCAS OFF as compared to the basic OH-58C (ref 8, app A). The SCAS ON controllability characteristics are shown in figures 15 through 18,of appendix E. The SCAS installation resulted in a slight decrease in the pitch and roll response. No change was qualitatively noted between controllability characteristics in the dummy sight or Rockwell sight configurations. The controllability characteristics of the OH-58C helicopter with MMS and three-axis SCAS are satisfactory.

Low Speed Flight Characteristics

27. The low speed flight characteristics were evaluated to determine the effects on handling qualities due to the installation of the dummy MMS and SCAS. The flights were conducted at the conditions shown in table 1. The low speed flight testing was conducted by stabilizing on a pace vehicle at a skid height of 25 feet at azimuths relative to the nose of the helicopter of 0, 90, 180 and 270 degrees. Low speed flight testing was conducted with SCAS ON and OFF and the test results are presented in figures 19 through 22 of appendix E.

28. The previously discussed light breakout (plus friction) forces in the directional control (para 14 through 16) caused the pilot to overcontrol the helicopter directionally. Any maneuver requiring frequent pedal inputs, i.e., rearward flight or left sideward flight, was susceptible to pilot directional overcontrol. The light directional control breakout forces (plus friction) and lack of a force gradient resulted in pilot overcontrol of the pedals and is a shortcoming.

29. Low speed forward flight was easily accomplished (HQRS-2) with SCAS ON or OFF even though a longitudinal control reversal was noted at 10-15 knots true airspeed (KTAS) (fig 19). This characteristic was previously noted in testing of the standard OH-58C (ref 8) but does not adversely affect the low speed forward flight characteristics. The longitudinal control gradient was essentially neutral from 25 to 40 KTAS but no adverse handling qualities were attributed to this characteristic. No noticeable differences were perceived between the Phase 1 and 2 configurations. The low speed forward flight characteristics met the requirements of paragraph 3.2.10 of MIL-H-8501A and are satisfactory.

30. In rearward flight with the SCAS OFF, large abrupt longitudinal control inputs were required to maintain pitch attitude (fig 19 and 20, app E). This characteristic is similar to the standard OH-58C (ref 8). With SCAS disengaged, satisfactory stabilized rearward flight was unobtainable due to the tendency of the helicopter to pitch and yaw excessively. The large pitch and yaw excursions required extensive pilot compensation (HQRS 6) to maintain helicopter attitudes within ±5 degrees. The maximum excursion of pilot control inputs required to maintain stabilized rearward flight are depicted by the "I" bars on figure 20. With SCAS engaged, the pilot workload to maintain stabilized rearward flight, was significantly reduced (HQRS 3). No differences in the low speed characteristics were perceived between Phase 1 and 2 configurations. The control margins and gradients were similar to the standard OH-58C with SCAS ON or OFF and the low speed rearward flight characteristics met the requirements of paragraph 3.2.1 of MIL-H-8501A with the

SCAS ON at the conditions tested. The addition of the three-axis SCAS significantly reduced the pilot compensation required to maintain stabilized rearward flight and is an enhancing characteristic.

31. In left sideward flight with the SCAS disengaged, no handling quality changes were noted from those reported in previous testing (ref 8). Smooth, stabilized left sideward flight was unobtainable with maximum pilot compensation (HQRS 7) due to the large pitch, roll, and yaw excursions of the helicopter. The maximum excursion of pilot control inputs for SCAS OFF left sideward flight is depicted by the "I" bars in figure 21, appendix E. The pilot workload required to maintain helicopter attitudes within ±5 degrees to compensate for the tendency of the helicopter to pitch, roll, and yaw with SCAS engaged was moderate (HQRS 4) (fig 22). The control margins and handling qualities characteristics were similar to the standard OH-58C and were satisfactory for the conditions tested. No qualitatively noticeable differences were perceived between the Phase 1 and 2 configurations. The addition of a three axis SCAS significantly reduces the pilot compensation required in left sideward flight and is an enhancing characteristic.

32. The low speed flight characteristics were qualitatively assessed as being unchanged with removal of the dummy MMS and installation of the Rockwell MMS. However, the airframe vibrations documented with the dummy MMS installation were significantly reduced with the Rockwell sight installation in all areas except right sideward flight and rearward flight (para 38). The qualitative evaluation of the Rockwell MMS revealed no adverse handling qualities that will prevent future operational testing of this MMS installation.

Aircraft System Failures

Simulated Engine Failures:

33. Simulated engine failures were conducted SCAS ON and OFF at the conditions listed in table 1. Sudden engine failures were simulated by trimming the aircraft at the test condition and rapidly closing the throttle to the idle position. The flight controls were held fixed at the trim position for two seconds (to simulate pilot reaction time) or until recovery was initiated to prevent exceeding aircraft limitations. The most frequent limit observed was rotor speed decay to the minimum transient rotor speed of 330 rpm, and a worst case, maximum delay time of 1.5 seconds was noted at 59 KCAS (fig 25) in high power climbs. Time histories of typical simulated sudden engine failures are shown in figures 23 through 25, for SCAS ON conditions. Simulated sudden engine failures with SCAS OFF produced aircraft responses essentially unchanged from those noted on the basic OH-58C helicopter. Except for the excessive rotor speed decay noted on the basic OH-58C aircraft and previously reported, the sudden engine failure characteristics of the OH-58C MMS helicopter with SCAS ON and OFF are satisfactory.

34. The SCAS ON sudden engine failure tests resulted in significantly smaller rate and attitude excursions from the trim condition than for similar test conditions with SCAS OFF. Adequate warning of the engine failure was available to the pilot in the form of moderate left yaw rate and attitude excursions of approximately one-half of that noted with SCAS OFF. Roll and pitch excursions were barely noticeable even during the collective lowering process. The sudden engine failure characteristics of the OH-58C MMS helicopter with SCAS ON were significantly improved over the SCAS OFF configuration but the rapid rotor speed decay discussed in paragraph 33 was unchanged.

SCAS Disengagements:

35. A limited system analysis of electrical power disconnects of the SCAS was completed during the PAE. This analysis consisted primarily of a ground investigation of the possible in-flight results of SCAS electrical power disconnects due to switch actuation or system failures. This investigation was first completed with rotors static and electrical and hydraulic power applied to the helicopter The SCAS inputs to the SCAS electrohydraulic actuators and the rotors were then evaluated as the various system switches and circuit breakers were actuated. The same checks were evaluated on the ground with the rotors turning at operating RPM (100%). The in-flight testing consisted of numerous SCAS disengagements by the use of the cyclic SCAS DISENGAGE switch. One in-flight disengagement was accomplished by pulling the SCAS INVERTER circuit breaker.

36. During the system analysis, it was determined that six methods of SCAS electrical power interruption were possible by the use of cockpit switches or circuit breakers. The power interruption possiblities are: actuation of the SCAS control panel PWR switch; both the CYCLIC and YAW control panel switches, or the cyclic SCAS DISENGAGE switch; or by pulling the SCAS CONTROL; SCAS INVERTER; or SCAS AC circuit breakers.

37. The SCAS analysis indicated that four of the above methods of interrupting electrical power would result in a hydraulic pressure shut-off to the electrohydraulic actuators. As the hydraulic pressure decreased, the SCAS actuator springs would gradually center the actuators to the null (no output signals) position. Such a system shutdown would occur for actuation of the cyclic SCAS DISENGAGE switch, disengagement of both the CYCLIC and YAW control panel switches, or by pulling either the SCAS CONTROL or SCAS AC circuit breakers. Figure 26, depicts the SCAS actuator feedback signals as a result of a cyclic SCAS DISENGAGE switch actuation in flight. The system analysis indicated that this SCAS actuator response was representative of the four electrical power disconnects noted above. The time delay between the electrical power interruption and the SCAS actuator response was approximately two seconds. It then required approximately two additional seconds for the SCAS actuator springs to counter the decreasing hydraulic pressure and center (null) the actuator. The flight evaluation with controls fixed for a cyclic SCAS DISENGAGE showed that sufficient delay time was available for the pilot to recover the helicopter from the mild SCAS inputs that resulted. The SCAS response to an electrical power interruption by the use of the cyclic SCAS DISENGAGE switch, by the disengagement of both CYCLIC and YAW control panel switches, or by pulling the SCAS CONTROL or SCAS AC circuit breakers was mild and provided sufficient pilot reaction time as determined by the limited scope of this evaluation. Further flight testing should be accomplished to determine the SCAS control inputs as a result of all possible electrical power interruptions.

38. One SCAS electrical power disconnect by the use of the SCAS INVERTER circuit breaker, was accomplished in flight. This electrical power interruption resulted in an immediate and simultaneous three-axis control input and the helicopter pitched up, rolled left, and yawed left. The SCAS actuator feedback signals that occurred as a result of the SCAS INVERTER circuit breaker actuation are shown in figure 27 and show that this electrical power interruption resulted in an immediate centering command to the actuators. System analysis indicated that such an immediate centering command signal could also occur if the SCAS control panel PWR switch were disengaged or if the single pulse module unit within the system

failed. The possibility of an immediate three-axis control input is further increased due to the location (para 41) and design (fig 1, app B) of the SCAS control panel PWR switch. The immediate and large control inputs that can occur as the result of the three electrical power interruptions noted will not provide the pilot with adequate reaction time to prevent large helicopter attitude changes. As the MMS operational testing mission will require low speed flight in close proximity to obstacles such as tree lines, the inability of the pilot to prevent large helicopter attitude changes due to the immediate three-axis inputs as a result of certain electrical power interruptions could result in a main or tail rotor strike accident. The possibility of uncommanded and immediate, large magnitude, three-axis control inputs as the result of a single switch actuation or SCAS component failure is a deficiency. The OH-58C helicopter with MMS should not be released for further testing with an operational SCAS until further flight testing of SCAS system failures and correction of any SCAS problems has been completed.

VIBRATION

39. The OH-58C airframe vibrations were documented during Phase 1 of the evaluation at the pilot, copilot, and dummy MMS cg locations. Excessive cockpit vibrations were noted in the forward flight airspeed range of 80 to 100 KCAS, right sideward flight, and rearward flight. The vibrations were at the main rotor 1 per revolution (1/rev) and 2/rev frequencies of 5.9 Hz and 11 8 Hz respectively, and increased the pilot workload significantly. The severest vibrations noted in forward flight occurred at 100 KCAS at the 2/rev frequency and were present in all three axes with maximum amplitudes of 0.31 to 0.33 g at the aircraft cg. The vibrati[illegible]s were attenuated in all three axes at the pilot and copilot seat[illegible] but the [illegible] accelerations were still as high as 0.24 g at the 2/rev frequency [illegible] characteristics were noted in right sideward and rearward flight at 30 to [illegible] but the severity of the vibrations were not as high. The longitudinal an[illegible] 2/rev accelerations were in the range of 0.12 to 0.15 g at the helicopter cg while the vertical vibrations did not exceed 0.04 g. However, the 2/rev vertical accelerations at the pilot and copilot seats in both rearward and right sideward flight were as high as 0.12 to 0.15 g. Upon completion of Phase 1, the contractor and AVRADCOM were briefed that excessive vibrations were present for the flight conditions noted above, but that they were not unsafe and the affect of the vibrations on future Rockwell sight operation could not be determined. The excessive 1/rev and 2/rev vibrations present in forward flight, right sideward flight and rearward flight would prevent sight operator utilization of the MMS controls and are a deficiency.

40. During the changeover from the dummy MMS to the Rockwell sight installation, BHT used a process of selective reassembly (app B) in an attempt to improve the MMS to main rotor mast alignment which facilitated the reduction of the MMS and airframe vibrations. During the qualitative evaluation of Phase 2, it was noted that the airframe vibrations at the pilot and copilot stations were significantly reduced during high speed forward flight and somewhat reduced in rearward flight. The only objectionable vibrations noted during the Rockwell sight evaluation was the 1/rev and 2/rev in right sideward and rearward flight. This vibration was noted as being typical of the vibrations normally associated with an out-of-track or out-of-balance rotor condition. The vibration was a mild periodic beat in the airframe at the main rotor 1/rev and 2/rev frequency and was noted in right sideward and rearward flight and in hovering flight with light winds (less than 10 knots) from the right rear of the helicopter. The low frequency 1/rev and 2/rev vibration noted with the Rockwell sight installation in right sideward and rearward flight will complicate sight operator utilization of the MMS controls and is a shortcoming.

COCKPIT EVALUATION

41. A limited cockpit evaluation was conducted to evaluate the changes due to the installation of the MMS and three-axis SCAS. The SCAS control panel consisted of a PUSH-ON/PUSH-OFF power switch, two electrical solenoid engage switches and two NO-GO lights. All switches were lighted to indicate the ON condition. The SCAS control power switch is on the left side of the SCAS control panel which was located on the forward, left side of the helicopter center console. Due to the PUSH-ON/PUSH-OFF design of the SCAS power switch and its close proximity to the sight operator's right knee, this switch is highly susceptible to inadvertent actuation. The high possibility of accidental actuation of the SCAS power switch contributes to the severity of the deficiency noted in paragraph 38. The PUSH-ON/PUSH-OFF design and location of the SCAS power switch makes it susceptible to inadvertent actuation and is a shortcoming.

42. The copilot flight controls were removed to allow for the installation of the operational MMS and cockpit system controls. The collective pitch lever was removed at its base where it attaches to a short bell crank extension in the cockpit floor. The bell crank and the short extension that receives the collective pitch lever were not removed. The left seat observer could reposition the collective pitch in flight by using the short bell crank extension. The uncovered left seat collective bell crank creates the possibility of collective control jamming should a hard object wedge between the exposed bell crank and the airframe. The unguarded copilot collective pitch lever bell crank could result in collective control jamming and is a deficiency. A rigid cover should be installed to prevent accidental movement or jamming of the exposed collective control components in the left seat area.

RELIABILITY AND MAINTAINABILITY

Mast-Standpipe Contact Indicators

43. The standpipe used to retain the dummy MMS to the aircraft extended through the main rotor mast. The standpipe was equipped with eight electrical contacts that would illuminate corresponding lights in the cockpit if mast to standpipe contact occurred. The lights were operational during Phase 1 of the PAE and illumination (indicating mast to standpipe contact) was to be treated as a grounding condition. Due to the limited clearance (1/4 inch) between the main rotor mast and the standpipe, the contacts should be retained for the operational sight. During the BHT installation of the Rockwell sight, it was found that there was enough physical space to allow for the retention of the mast to standpipe contact warning system. Although no contact occurred during the PAE, the main rotor mast to standpipe contacts should be retained throughout the Army operational testing of the OH-58C with the Rockwell MMS.

Flight Control Rigging

44. The main rotor and tail rotor flight control rigging was checked by USAAEFA personnel prior to the start of Phase 1 of the PAE. The length of the control tube to the right horn of the inner ring of the swashplate was not within the required tolerance of 8.89 to 8.93 inches. This control tube was 8.75 inches in length and resulted in an approximate one degree misalignment between the main rotor mast and the swashplate. This out-of-rig condition was determined to be safe and testing without re-rigging was approved to maintain comparability of test data with the completed BHT testing. No adverse handling qualities were noted that could be

attributed to the out-of-rig condition. During the removal of the dummy MMS and installation of the Rockwell MMS, BHT re-rigged the flight controls to the correct dimensions. During the qualitative evaluation of Phase 2, no changes in the helicopter handling qualities were noted that could be attributed to the change in lateral rigging.

SCAS Actuator Null Positions

45. During the early stages of Phase 1, a limited analysis of the entire SCAS was completed to determine the possible results of various system component failures during flight. The null (no SCAS flight control input) position of the SCAS actuators might not fall within the normal mid-stroke of the actuator as required. Since the loss of certain AC electrical signals drive the SCAS actuator to the null position, with a failure such as the loss of inverter power, the actuators could "hard over" to greater travel distances than would be normal. This larger than "return to center" actuator travel command would amplify the severity of the deficiency noted in paragraph 38. A method of checking voltage input signals to the SCAS actuators is available to insure the actuator null positions are at the normal midstroke location. The maintenance procedures for centering the null positions of the SCAS actuators should be included as a part of the periodic maintenance inspections on any installed BHT Model 570B SCAS.

CONCLUSIONS

GENERAL

46. The following general conclusions were reached in Phases 1 and 2 of the PAE:

a. No differences were noted in handling qualities between the dummy and Rockwell sight installations. The handling quality characteristics of the OH-58C configured with a MMS are satisfactory and will not preclude future operational testing of the OH-58C MMS concept.

b. The Model 570B three axis SCAS requires further failure analysis, flight testing, and correction of any SCAS problems prior to release of the OH-58C with an operational SCAS to operational test agencies (para 37 and 38).

c. Reconfiguration of the OH-58C from the dummy sight installation to the Rockwell sight indicates that selective assembly of close tolerance mast and mast mounted components may be required to achieve acceptable airframe vibration levels (para 40).

d. The main rotor controls were out of rig and resulted in approximately 1 degree of mast to swashplate misalignment for Phase 1 of the PAE. The rigging was corrected for Phase 2 testing and no changes in handling qualities could be detected (para 44).

ENHANCING CHARACTERISTICS

47. The installation of a three-axis SCAS significantly improves the handling quality characteristics of the OH-58C, particularly in the low speed flight regime, and is an enhancing characteristic (para 30 and 31).

DEFICIENCIES

48. The following deficiencies were identified in Phase 1 and are listed in decreasing order of importance.

a. The uncommanded and immediate, large-magnitude, three-axis control inputs as the result of a single SCAS switch actuation or component failure (para 38).

b. The unguarded copilot collective pitch lever bell crank (copilot's collective stick removed) which could result in collective control jamming (para 42).

c. The divergent long period oscillation noted in high rates of climb (greater than 1000 fpm) at 55 KIAS (para 21). Corrected during Phase 2 (para 49).

d. The excessive low frequency airframe vibrations noted in forward flight, rearward, and right sideward flight (para 39). Downgraded to a shortcoming during Phase 2 (para 50).

49. The addition of a lag rate term within the pitch axis SCAS logic prior to the Phase 2 testing eliminated the deficiency listed in paragraph 48c (para 22).

50. The selective assembly of close tolerance mast and mast mounted components prior to Phase 2 testing resulted in the deficiency listed in paragraph 48 being reduced to a shortcoming (para 40).

SHORTCOMINGS

51. The following shortcomings were noted in Phases 1 and 2 and are listed in decreasing order of importance.

a. The limited flight path normal acceleration envelope developed for the OH-58C with installed MMS (para 20).

b. The PUSH-ON, PUSH-OFF design and the location of the SCAS power switch (para 41).

c. The light directional control breakout (plus friction) force (para 16 and 28).

d. The lack of a directional control force gradient system (para 16).

e. The 1/rev and 2/rev airframe vibrations noted in right sideward and rearward flight (para 40).

SPECIFICATION COMPLIANCE

52. Within the scope of this test the OH-58C with MMS and three axis SCAS failed to meet the following requirements of the specification MIL-H-8501A:

a. Paragraph 3.3.10. The lack of a force gradient system in the directional controls fails to meet the requirement of the specification in that positive self-centering is not present (para 14).

b. Paragraph 3.3.12. The directional control system breakout forces were less than required by 1 to 2.5 pounds during Phase 1 testing (para 16).

RECOMMENDATIONS

53. Correct the deficiencies listed in paragraphs 48a and 48b prior to release of the helicopter with an operational SCAS to other test agencies.

54. Correct the shortcomings listed in paragraph 51a through 51e as soon as possible.

55. Further testing be accomplished to expand the normal acceleration envelope of the OH-58C with MMS prior to operational use (para 20).

56. Include the following caution in the MMS operational testing airworthiness release:

CAUTION

The +0.6 to 1.4 g flight path normal acceleration limitations can easily be exceeded during mission maneuvers.

57. Further testing should be accomplished to fully evaluate the OH-58C SCAS lagged pitch rate term affect on the longitudinal long term dynamic stability at high power climb conditions and determine any affects on handling qualities throughout the entire flight envelope (para 22).

58. Further testing should be accomplished to determine the SCAS control inputs as a result of all possible electrical power interruptions (para 37).

59. The OH-58C helicopter with MMS installed should not be released for further testing with an operational SCAS until further flight testing of system failures has been accomplished and SCAS problems corrected (para 38).

60. The construction and installation of a rigid cover for the copilot's collective control bell crank should be accomplished to prevent accidental collective control jamming (para 42).

61. The main rotor mast to standpipe contacts should remain operational throughout the Army operational testing of the OH-58C with MMS (para 43).

62. The maintenance procedures for centering the null positions of the SCAS actuators should be included as part of the periodic maintenance inspections on any installed BHT Model 570B SCAS (para 45).

APPENDIX A. REFERENCES

1. Letter, AVRADCOM, DRDAV-EQI, 11 April 1978, subject: Preliminary Airworthiness Evaluation, OH-58C Configured with a Mast Mounted Sight.

2. Message, AVRADCOM 271945Z, September 1979, subject: Revised Test Plan and Test Schedule.

3. Technical Manual, TM55-1520-235-10, *Operator's Manual, Army OH-58C Helicopter*, 7 April 1978, with changes 1 through 6 and 8.

4. Letter, AVRADCOM DRDAV-DI, 15 October 1979, subject: Airworthiness Release for AVRADCOM & USAAEFA Project No. 78-09.

5. Letter, AVRADCOM DRDAV-DI, 27 November 1979, subject: Airworthiness Release for USAAEFA to Conduct Qualitative Flight Evaluation of OH-58C Helicopter with Rockwell International Mast Mounted Sight Installed.

6. Military Specification, MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities; General Requirements For*, 7 September 1961, with Amendment 1, 3 April 1962.

7. Naval Test Pilot School Flight Test Manual, Naval Air Test Center, USNTPS-FTM-No. 101, *Helicopter Stability and Control*, June 1968.

8. Pilot Report, *Handling Qualities of an OH-58C Helicopter with Mast Mounted Visionics, Part II, Test Results, BHT 206-099-423*, 16 May 1978 with Revision D, 9 June 1980.

9. Final Report, USAAEFA Project No. 76-11-2, *Airworthiness and Flight Characteristics Evaluation OH-58C Interim Scout Helicopter*, March 1979.

10. Army Regulation No. 310-25, *Dictionary of US Army Terms (Short Title: AD)*, 15 September 1975, with changes 1 and 2.

APPENDIX B. DESCRIPTION

AIRCRAFT

Weight and Balance

1. The helicopter configured with the dummy MMS and instrumentation was weighed with no fuel and with full fuel by BHT and witnessed by a USAAEFA quality control representative. The helicopter was also weighed by BHT after the reconfiguration to the Rockwell MMS installation with its additional instrumentation. The nonrotating sight assemblies were similar in weight. The weight and longitudinal cg data are presented below:

Dummy Sight Installation

Empty fuel weight:	2383 lb at 114.64 in. cg
Full fuel weight:	2840 lb at 115.73 in. cg

Rockwell Sight Installation

Empty fuel weight:	2265 lb at 115.42 in. cg
Full fuel weight:	2722 lb at 116.52 in. cg

Control Rigging

2. A complete flight control rigging check was completed by BHT and monitored by USAAEFA quality control personnel prior to the conduct of Phase 1 of the PAE. The rigging was also rechecked by BHT after the helicopter reconfiguration to the Rockwell MMS installation. The data for the Phase 1 rigging check is presented in table 1 of this appendix.

STABILITY AND CONTROL AUGMENTATION SYSTEM

General

3. The standard configuration OH-58C was modified by removing the vulnerability reduction directional controls, and adding a boosted tail rotor control system, and a Model 570B three-axis stability and control augumentation system which was manufactured by BHT. The system consists of a control panel, a sensor amplifier unit, three electrohydraulic actuators, and three control motion transducers. The major components are shown in figure A and a block diagram is shown in figure B.

Control Panel

4. The control panel contains a PUSH ON/OFF power switch for applying primary power to the system and two PUSH ON/OFF magnetic latching switches for engagement or disengagement of the cyclic and yaw channels. Two "NO GO" lights warn of unsafe SCAS engagement conditions. Conventional edge lighting is used for night illumination of the panel.

Table 1. Flight Control Rigging

Swashplate Rigging[1]		
Stick Position	**Swashplate Angle**	
Neutral	Forward Right	5° 18' 0° 36'
Fore and aft (full throw)	Forward Aft	18° 20' 6° 45'
Lateral (full throw)	Left Right	6° 54' 6° 25'
Collective pitch (blade angle)	Down Up	-0° 25' 15° 44'
Tail Rotor Rigging[2]		
Blade angle	Left Right	19° 20' 10° 40'
Swashplate Horn Pitch Links[3]		
Neutral stick	Left horn Right horn Collective	8.90 inches 8.75 inches 1.98 inches

[1] 50% collective with hydraulic boost ON measured relative to mast
[2] Geometric-pitch angle to the plane of rotation
[3] Limits for right and left horn links = 8.89 to 8.93 inches

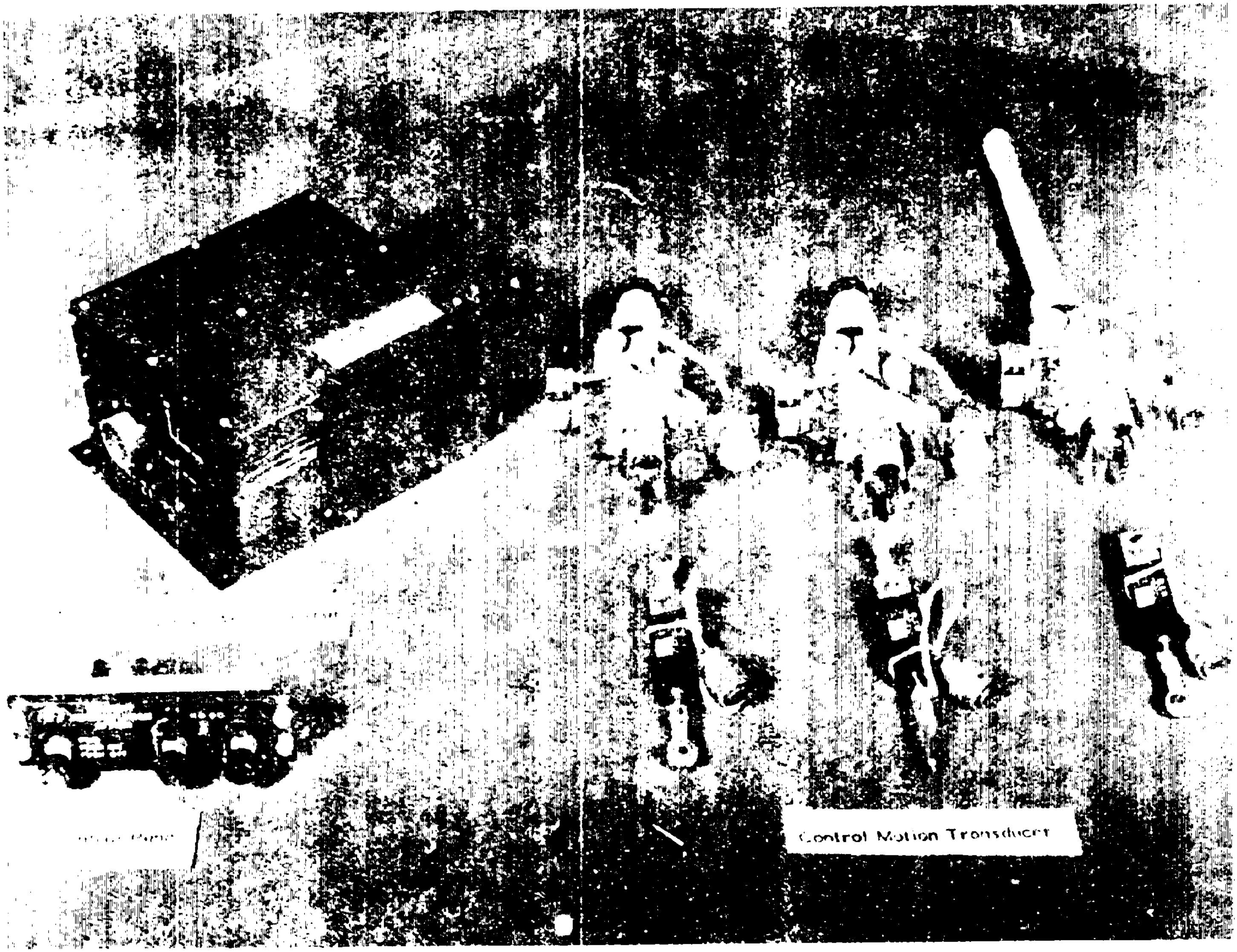


Figure 4. Stability and Control Augmentation System Components

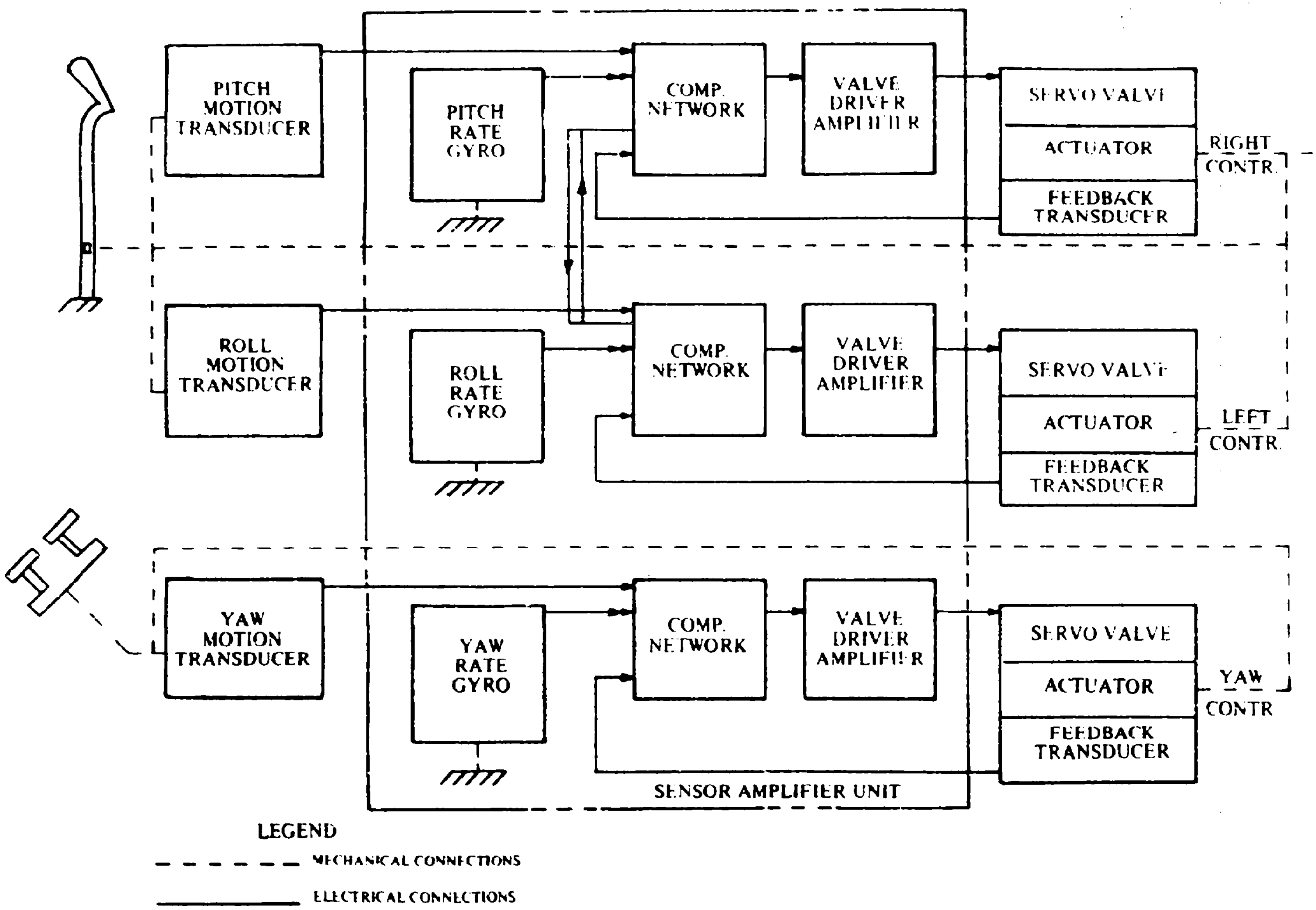


Figure B. Stability and Control Augmentation System Block Diagram

Sensor Amplifier Unit

5. The sensor amplifier unit contains three rate gyros which measure the rate of displacement of the airframe from a trimmed attitude. One gyro is oriented for each axis of measurement. All three gyros are mounted on a single base for replacement as a unit or the gyros can be individually replaced. There are three plug-in circuit boards; one each for the yaw, pitch and roll channels. Each board contains compensating networks, a valve driver amplifier, and a built-in test equipment (BITE) module. Test switches on the outside of the case marked "ACTR TEST" and "GYRO TEST" are for use by maintenance personnel. Inside the case, adjacent to each plug-in circuit board socket, is a "NO GO" warning light. The yaw channel light is connected in parallel with its associated light on the control panel. The cyclic light on the control panel will light if either the roll or pitch light in the sensor amplifier unit is illuminated. During the Rockwell sight installation BHT modified the pitch channel of the SCAS circuitry by the addition of a lag rate term within the compensation network (fig C). This modification increased the damping ratio of the long period oscillations.

SCAS Actuators

6. There are three, limited authority, electrohydraulic, series type actuators installed on the flight control linkage. The authority of each actuator is limited to approximately 10 to 15 percent of the total pilot control authority in each direction. To provide a positive safety feature the actuators are self-centering by built-in springs and are mechanically locked in the center position in the event of electrical or hydraulic power failure, and when the system is turned off. The rate of actuator response to electrical disengagements will vary according to the method of disengagement.

Control-Motion Transducers

7. Control-motion transducers are installed in the pitch, roll and yaw axes of the pilot's flight control system. These units measure physical movement of the controls in each axis and provide this information electrically to the compensation networks in the Sensor Amplifier Unit. Thus the SCAS can distinguish between pilot control inputs and airframe displacements that are caused by external disturbances.

DUMMY MAST MOUNTED SIGHT

8. The dummy mast mounted sight installed for Phase I of the PAE consisted of a vibration isolated weight assembly and nonrotating cover that was similar to the Rockwell International Sight in size and shape. Photographs 1 and 2 show the dummy MMS as installed for the PAE. The weights were vibration isolated by the use of a focal plate assembly at the base of the dummy installation. The entire assembly was mounted to the main transmission by a through-the-mast standpipe. Table 2 presents a breakdown of the dummy MMS components and individual weights. The use of ballast at various airframe locations and the installed BHT instrumentation package provided a test weight and longitudinal cg location that closely approximated the proposed Rockwell International Sight configuration.

ROCKWELL INTERNATIONAL MAST MOUNTED SIGHT

9. The Mast Mounted Sight Designator system produced by Rockwell International, Missile Systems Division, Columbus, Ohio was designated for installation on an

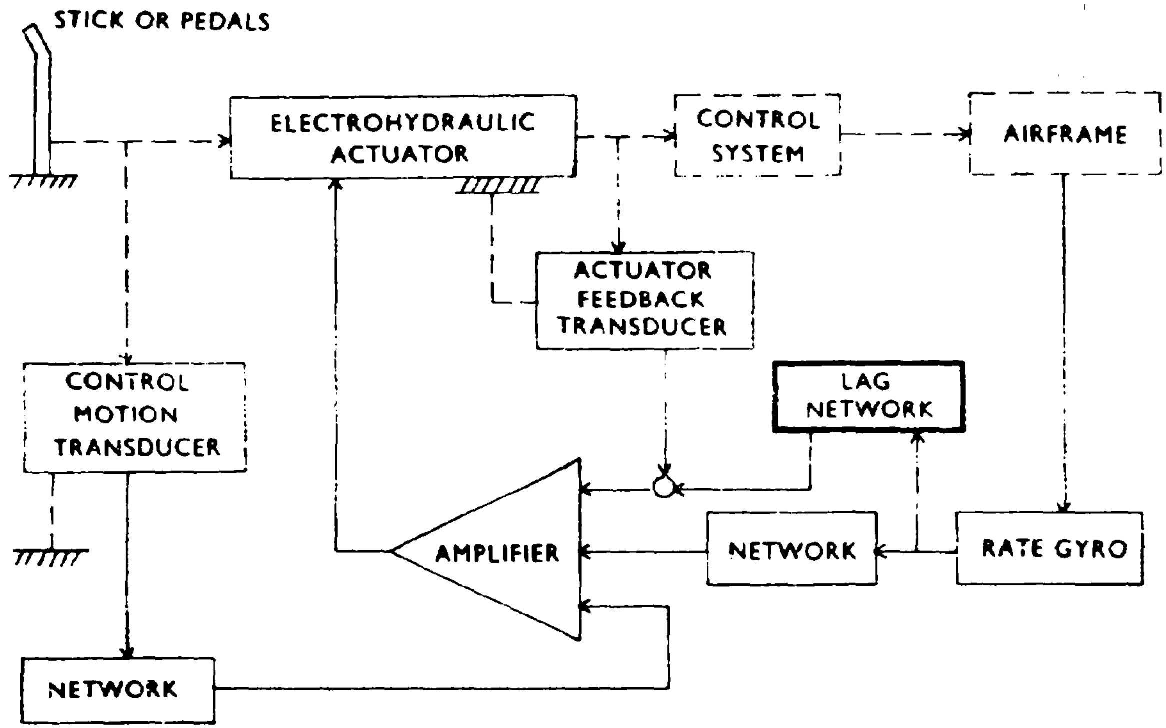


Figure C. Lag Network in Longitudinal SCAS System

Photo 1. Dummy Mast Mounted Sight - Side View

Photo 2. Dummy Mast Mounted Sight

Table 2. Dummy MMS Description

Component	BHT Part Number[1]	Weight
Dummy sight:		
Weight support	206-812-004-9	9.7
Weight base plate	699A252-1	13.3
Weights (15)	699A252-3	39.6
Instrumentation cover:[2]		
Non-rotating cover		8.5
Focal mount:		
Focal mount assembly[2]	206-812-010-105	19.1
Standpipe assembly:		
Standpipe	206-840-004-109	3.1
Spacer	206-840-004-107	0.5
Support assembly[2]	206-840-005-103	21.8
Cable assembly		2.0
Total dummy MMS installation		118.5

[1] BHT supplied part numbers when available.
[2] Includes weight of instrumentation.

OH-58C to permit target acquisition and laser ranging and designation from masked positions to improve combat survivability. The Rockwell MMS consists of a sealed pressurized housing containing a silicon vidicon television camera, an Integrated Laser System FW-103 laser designator, and associated optics. These components are mounted on a three-gimbaled, servo driven platform which was located atop the main rotor mast (photos 3 and 4). The laser range receiver was not installed for this test. A pantograph-mounted control and display unit was located on the floor at the copilot's station. A servo electronics and interface chassis is mounted on the floor on the left side of the passenger compartment.

10. A camera/tracker chassis was mounted on the left side of the rear seat. The prototype system also included the following as instrumentation: a television monitor, video tape recorder, and time code/video character generator. These items were mounted on the left side of the rear seat deck. The baggage compartment contained the following components: a 14 channel analog-data-recording/reproduction system, two instrumentation power supplies, and an instrumentation breakout box. The Rockwell MMS utilized in Phase 2 of this PAE consisted of the following hardware:

MMS Components

Camera tracker electronics assembly
Cabling interface
Pilot's imaging display and controller
Static inverter
Television monitor
Servo electronics assembly
Operator's imaging display and controller
Mast mounted sight assembly
Laser lock

Instrumentation Components

Video tape recorder
Instrumentation power supply
Instrumentation breakout box
Time code generator
Character generator

The entire system as installed for Phase 2 testing weighed approximately 260 pounds.

11. During the dummy MMS testing the vibration levels were unacceptable at the pilot and copilot stations, and attempts to reduce these vibrations resulted in unacceptable vibratory loads at the MMS cg. Prior to the installation of the Rockwell sight, the dummy MMS components were reassembled on the bench and measured for component allignment. It was found that the nonrotating platform had a 0.026 inch radial runout and a 0.020 face runout with respect to the mast axis of rotation. The contractor determined that this runout was sufficient to cause a 1/rev vibration at the MMS cg and would be susceptible to dynamic amplification due to the focal mount system designed to isloate 2/rev vibrations. In an attempt to improve the mast to sight allignment, the following components were mixed and matched:

2 sets of MMS support assemblies

Photo 3. Rockwell International Mast Mounted Sight

Photo 4. Rockwell International Mast Mounted Sight

1 with a small rotating base - BHT P/N 206-840-005-105

1 with a large rotating base - BHT P/N 206-840-005-101

3 main rotor masts - BHT P/N 206-010-332-13

2 main rotor trunnions - BHT P/N 206-011-113-1

2 pairs of split-cone sets - BHT P/N 206-010-003-1

It was found that the swapping of of the main rotor trunnions resulted in the most significant change to the mast to nonrotating platform allignment. By selectively matching the above components, the final configuration resulted in a face runout of 0.002 inch and a radial runout of 0.004 inch with respect to the mast axis of rotation. These selected parts were disassembled and reassembled 5 times with repeatable results, and when used in the Rockwell sight installation, the vibrations were significantly reduced (para 40).

APPENDIX C. INSTRUMENTATION

1. The test instrumentation was installed, calibrated, and maintained by BHT. Data were obtained from calibrated instrumentation and were recorded on magnetic tape and/or displayed in the cockpit. The data acquisition system consisted of various transducers, signal conditioning units, frequency multiplexing techniques, and a one-inch, 14-track Inter-Range Instrumentation Group intermediate band recorder. Various specialized indicators displayed data to the pilot and engineer on board the aircraft continuously during the flight. A flight test boom was mounted on the nose of the aircraft with the following equipment: swiveling pitot-static tube, sideslip vane, angle-of-attack vane, and total temperature sensor.

2. Specialized and/or calibrated cockpit monitored parameters are listed below.

Airspeed (boom)
Altitude (boom)
Angle of sideslip
CG normal acceleration
Control positions
- Longitudinal
- Lateral
- Directional
- Collective

Engine torque pressure
Ambient air temperature
Fuel quantity (ship's system)
Gas generator speed (ship's system)
Rotor speed
Turbine outlet temperature (ship's system)
Radar altimeter (ship's system)
Event switch
Instrumentation controls
Record counter

3. Parameters recorded on tape were as follows:

Airspeed (boom)
Altitude (boom)
Attitudes
- Pitch
- Roll
- Yaw

Rates
- Pitch
- Roll
- Yaw

Angle-of-sideslip
Angle-of-attack
Control positions
- Longitudinal
- Lateral
- Directional
- Collective
- Throttle

SCAS actuator feedback signal (SCAS positions)

- Longitudinal
- Lateral
- Directional

Accelerometers

Center-of-gravity

- Longitudinal
- Lateral
- Vertical

Pilots

- Longitudinal
- Lateral
- Vertical

Copilots

- Longitudinal
- Lateral
- Vertical

Mast mounted sight

- Longitudinal
- Lateral
- Vertical

Focal plate position

- Longitudinal
- Lateral

Engine torque pressure

Rotor speed

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. Conventional test techniques were used in the evaluation. Detailed descriptions of all test techniques are contained in reference 7, appendix A. Definition of deficiencies and shortcomings are stipulated in Army Regulation 310-25 (ref 9). The handling qualities were evaluated in accordance with the Handling Qualities Rating Scale (HQRS) contained in figure 1.

CONTROL SYSTEM CHARACTERISTICS

2. These tests were conducted on the ground with hydraulic and electrical power provided by ground power units. A hand-held force gage was used to measure the force required to move the directional control in incremental displacements to the limits of travel in both directions.

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

3. These tests were accomplished by establishing a trim condition (airspeed/power combination) with zero control forces at each airspeed.

STATIC LONGITUDINAL STABILITY

4. These tests were accomplished by establishing a trim condition (airspeed/power combination) with zero control forces. Without releasing force trim, or changing the collective position, or rotor speed, the helicopter was stabilized at incremental airspeeds, both faster and slower than the trim airspeed, using cyclic only.

MANEUVERING STABILITY

5. The variation of longitudinal control position and force with normal acceleration were determined during steady turns, symmetrical pull-ups and push-overs. Each test consisted of incrementally increasing normal acceleration (load factor) while holding collective position constant. Steady turns, in both directions, were accomplished by stabilizing and trimming in level unaccelerated flight at the desired test airspeed. Load factor was increased to the maximum allowable by incrementally increasing bank angle. Zero sideslip, constant airspeed, and fixed collective were maintained during the turn. Rotor speed was not adjusted during the turn except to maintain the rotor speed within the power-on limit. Data were gathered within 1000 feet of the specified test altitude.

6. The symmetrical pull-up tests were performed by establishing a level unaccelerated flight condition at the target trim airspeed. All control forces were trimmed to zero. Without changing the trim collective position and rotor speed, the helicopter was decelerated and a climb initiated with cyclic, then the nose was lowered and the helicopter was allowed to accelerate to beyond the trim airspeed. The longitudinal control was then rapidly displaced against a control fixture so that the desired normal acceleration was obtained as the aircraft decelerated through trim airspeed in a level attitude. Small lateral control inputs were used to maintain a level attitude.

7. The symmetrical push-over tests were performed by establishing a level unaccelerated flight condition at the target trim airspeed. All control forces were trimmed to zero. While maintaining the trim collective position and rotor speed, the aircraft was pitched nose down to accelerate to an airspeed greater than trim. Using cyclic only, the aircraft was then decelerated to an airspeed slightly higher than trim. A rapid displacement of the longitudinal control forward against the fixture, was initiated and the desired normal acceleration was obtained as the airspeed reached trim in a level attitude. The pull-up and push-over tests were continued for increasing step inputs until the desired normal acceleration range was reached.

DYNAMIC STABILITY

8. The longitudinal long term dynamic response characteristics were determined in and forward flight. The forward flight tests were initiated from zero sideslip, level flight and climbing flight conditions. The tests were performed with and without the stability augmentation system activated. The forward flight longitudinal long term dynamic response characteristics were determined by first stabilizing at the desired trim conditions and trimming all control forces to zero. Without retrimming, the longitudinal control was used to decrease or increase the indicated airspeed. The controls were then returned to the trim position and held fixed while the aircraft response was recorded.

9. The dynamic lateral-directional tests included evaluating the lateral-directional oscillations (Dutch-Roll) and spiral stability characteristics. The lateral-directional response characteristics were obtained by trimming in level flight at the desired airspeed and altitude and recording the trim conditions. The lateral-directional motion was then excited by using the following methods: release from a sideslip, and lateral or directional control doublets.The release from a sideslip was accomplished by establishing a steady heading sideslip and returning all controls to trim in one sharp, deliberate motion. The control pulse inputs were performed by rapidly displacing the desired control approximately one inch, holding the input for 0.5 seconds and returning the control to the trim position All controls were held fixed following the control input.

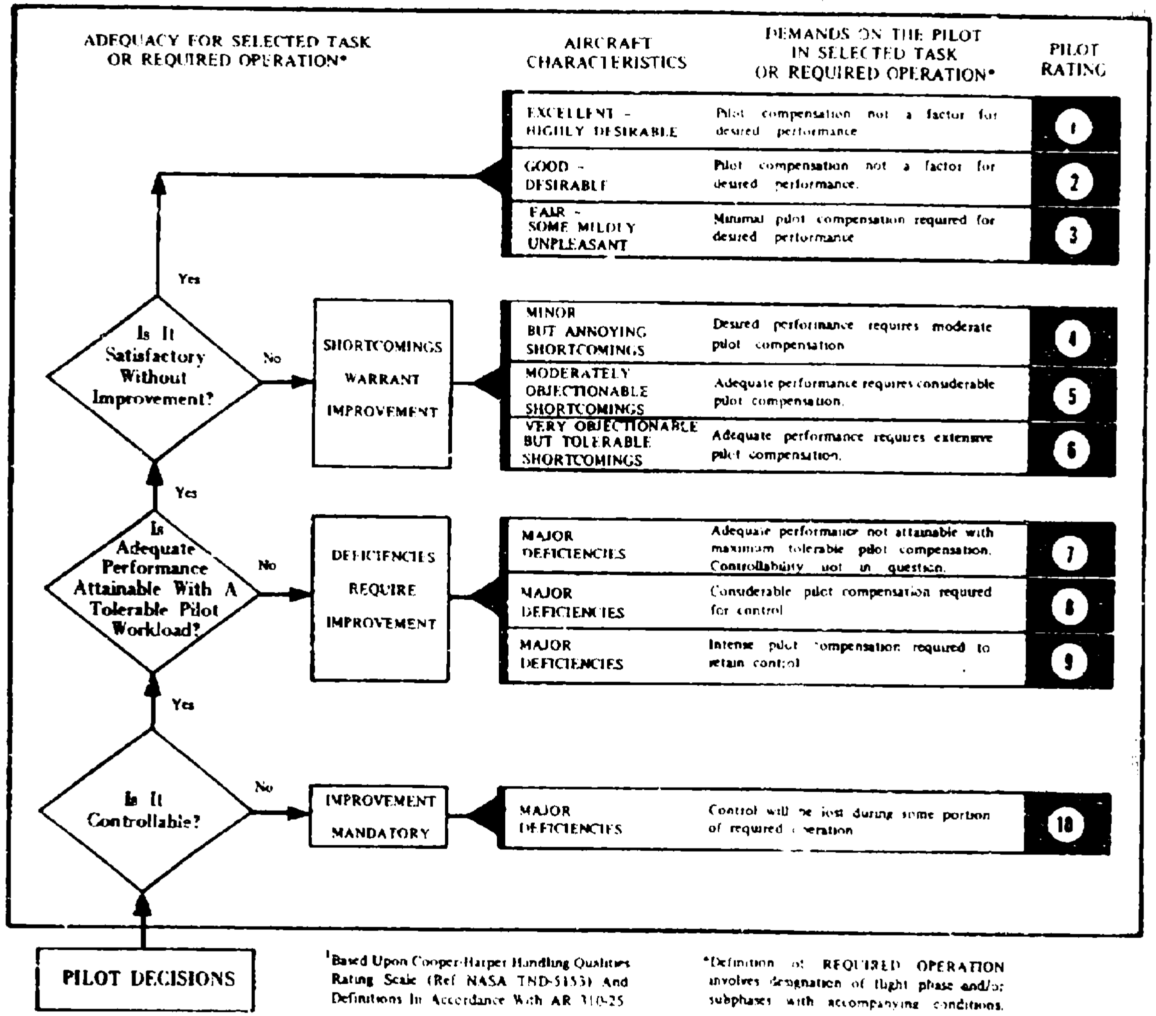
CONTROLLABILITY

10. The tests were accomplished by applying longitudinal and lateral step inputs of at least one inch in both directions. The step input was made by rapidly displacing the control from trim, against a control fixture. The input was rigidly held until a steady state rate was obtained or recovery was necessary. A build-up of increasing step displacement was conducted. All controls, other than the input control remained fixed. In forward flight the inputs were initiated during unaccelerated zero sideslip level. The hover tests were conducted in winds of three knots or less at a skid height of 50 feet.

LOW-SPEED FLIGHT CHARACTERISTICS

11. Testing was accomplished using the ground pace vehicle method, in winds of three knots or less. Tests were flown in five-knot increments from a hover to 40 knots forward, 35 knots left and right sideward and 30 knots rearward, unless limited by adverse performance or degraded handling qualities. All tests were conducted by stabilizing at a skid height of 25 feet. The pace vehicle then established the desired speed using a calibrated fifth wheel for a reference ground speed. The

test aircraft was flown in formation with the pace vehicle utilizing the ground and the aircraft's horizontal situation indicator for heading stabilization. Data were recorded when the relative motion between the aircraft and pace vehicle was zero and the radar altimeter indicated no vertical displacement from the desired skid height.



[1]Based Upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND-5153) And Definitions In Accordance With AR 310-25

*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions.

Figure 1. Handling Qualities Rating Scale

APPENDIX E TEST DATA

Index

FIGURE 1
BOOST ON DIRECTIONAL CONTROL FORCE
OH-58C S/N 69-16214

NOTES:
1. TOTAL DIRECTION CONTROL TRAVEL = 6.1 INCHES
2. TEST CONDUCTED ON THE GROUND WITH ROTOR STATIC AND WITH HYDRAULIC PRESSURE SUPPLIED BY AN EXTERNAL SOURCE
3. STARTING POINT WITH PEDALS CENTERED
4. SOLID SYMBOL DENOTES START POINT
5. PHASE 1

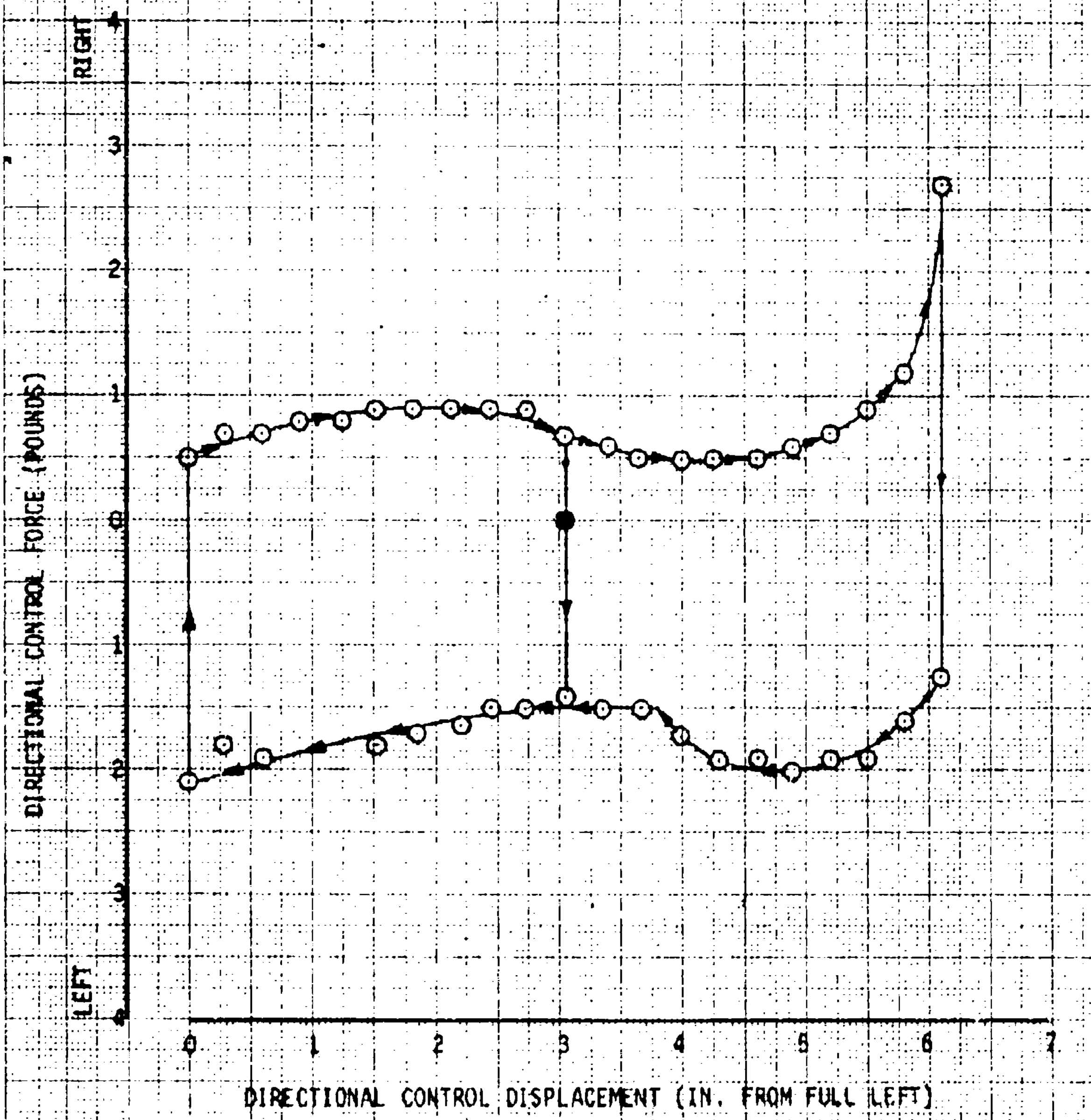


FIGURE 2
BOOST ON DIRECTIONAL CONTROL FORCE
OH-58C S/N 68-16214

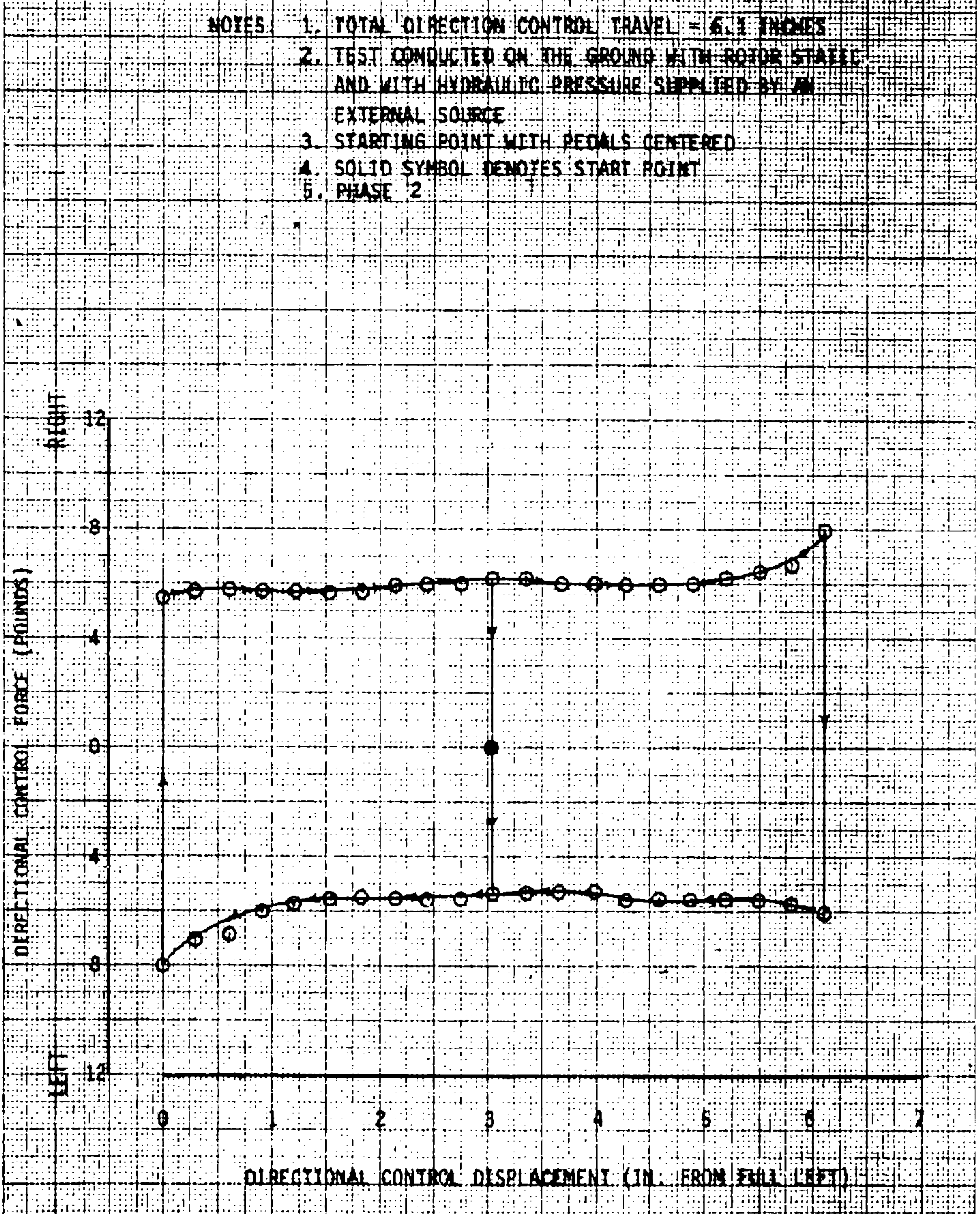


FIGURE 9
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
OH-58C USA SN 69-16214

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	FLIGHT CONDITION
○	318[illegible]	109.9(MID)	0.2(RT)	2720	22.5	355	0.00343	LEVEL
△	3140	109.8(MID)	0.2(RT)	2780	23.0	349	0.00351	LEVEL

NOTES: 1. CONFIGURATION: CLEAN, DOORS ON
2. MAST MOUNTED SIGHT INSTALLED (DUMMY)

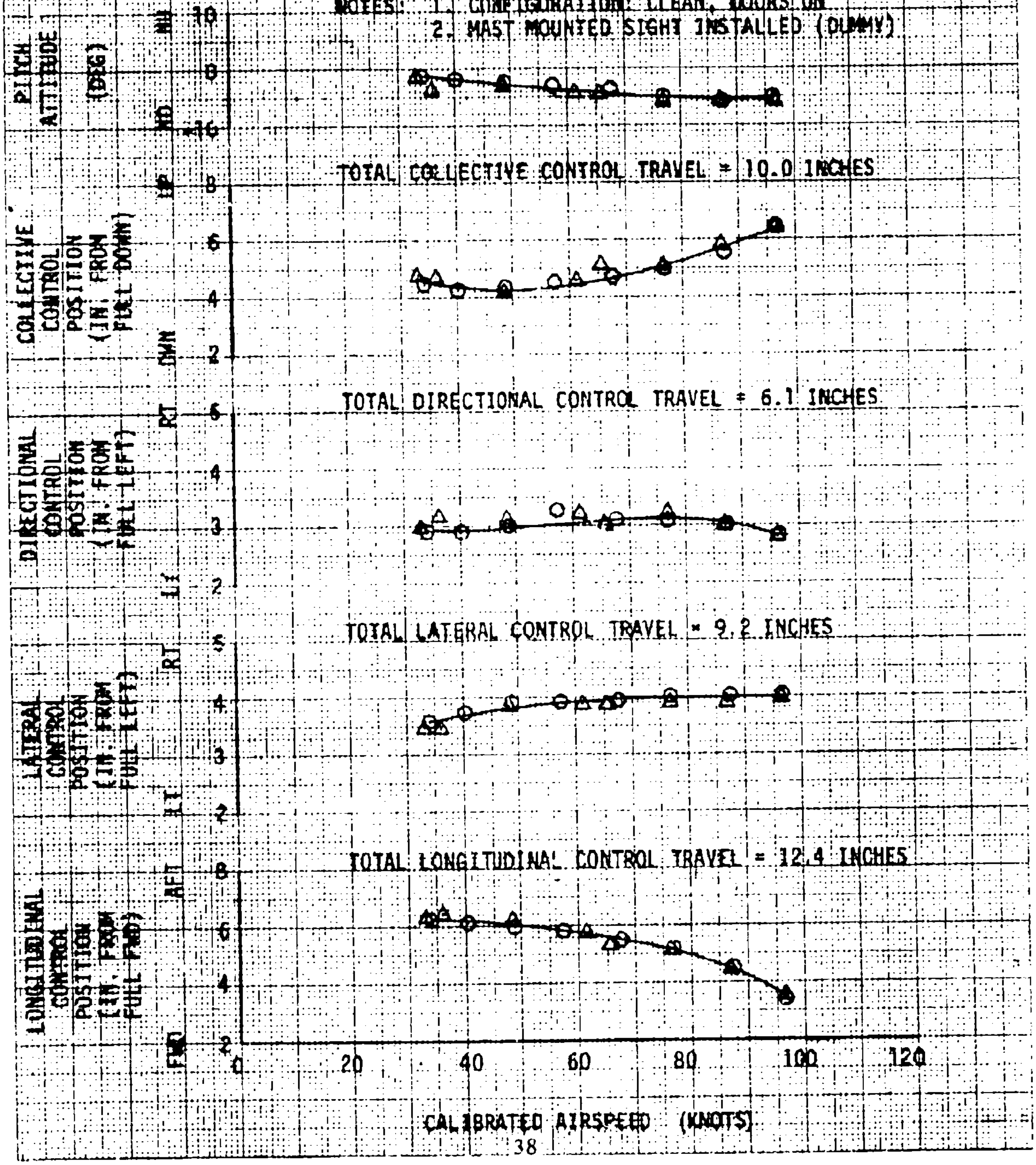


FIGURE 4
COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY
OH-58C USA S/N 69-16214

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN)	AVG CG LOCATION LAT (IN)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	TRIM FLIGHT CONDITION
○	3200	109.6(MID)	0.2(RT)	3680	14.0	354	0.00357	LEVEL
□	3160	109.5(MID)	0.2(RT)	4000	13.5	354	0.00356	LEVEL

NOTES: 1. CONFIGURATION: CLEAN, DOORS ON
2. SHADED SYMBOLS DENOTE TRIM
3. MAST MOUNTED SIGHT INSTALLED (DUMMY)

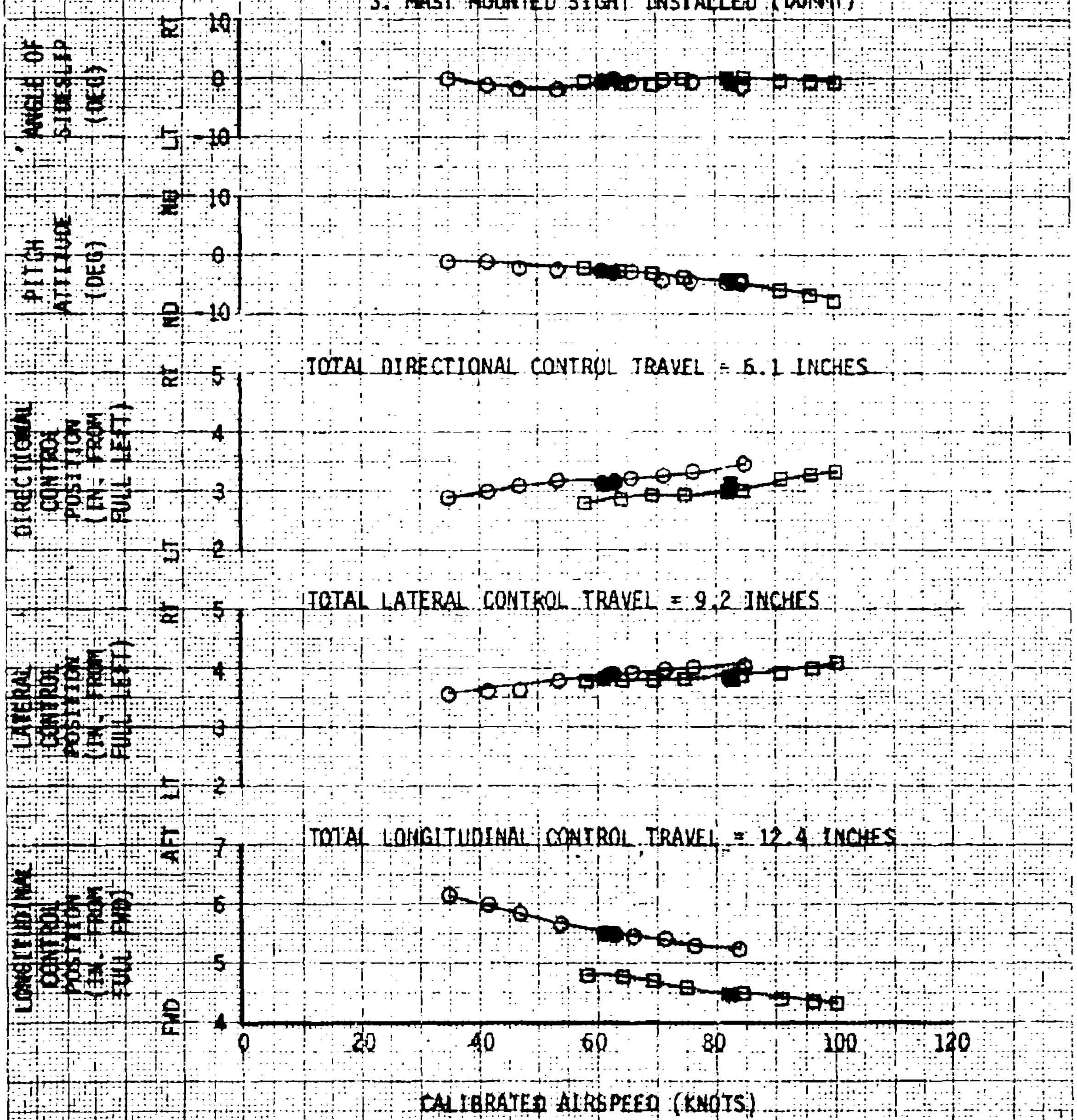
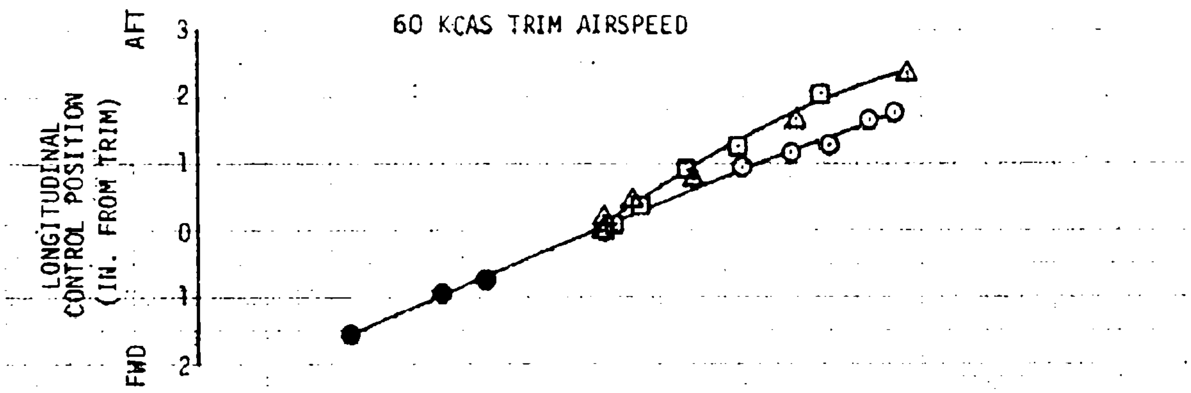


FIGURE 5
MANEUVERING STABILITY
OH-58C USA SN 69-16214

AVG GROSS WEIGHT (LB)	AV CG LOCATION LONG (IN.)	AV CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
3100	109.5(MID)	0.2(RT)	5180	14.5	354	0.00362	MAST MOUNTED SIGHT (DUMMY)

NOTE: SCAS ON

SYMBOLS: ○ PULL UP
● PUSH OVER
□ RIGHT WIND UP TURN
△ LEFT WIND UP TURN



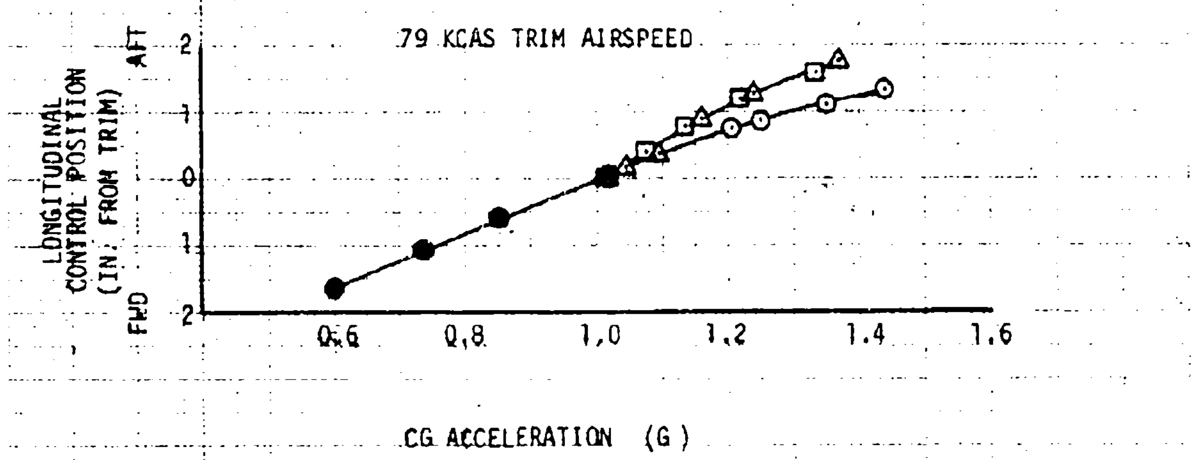
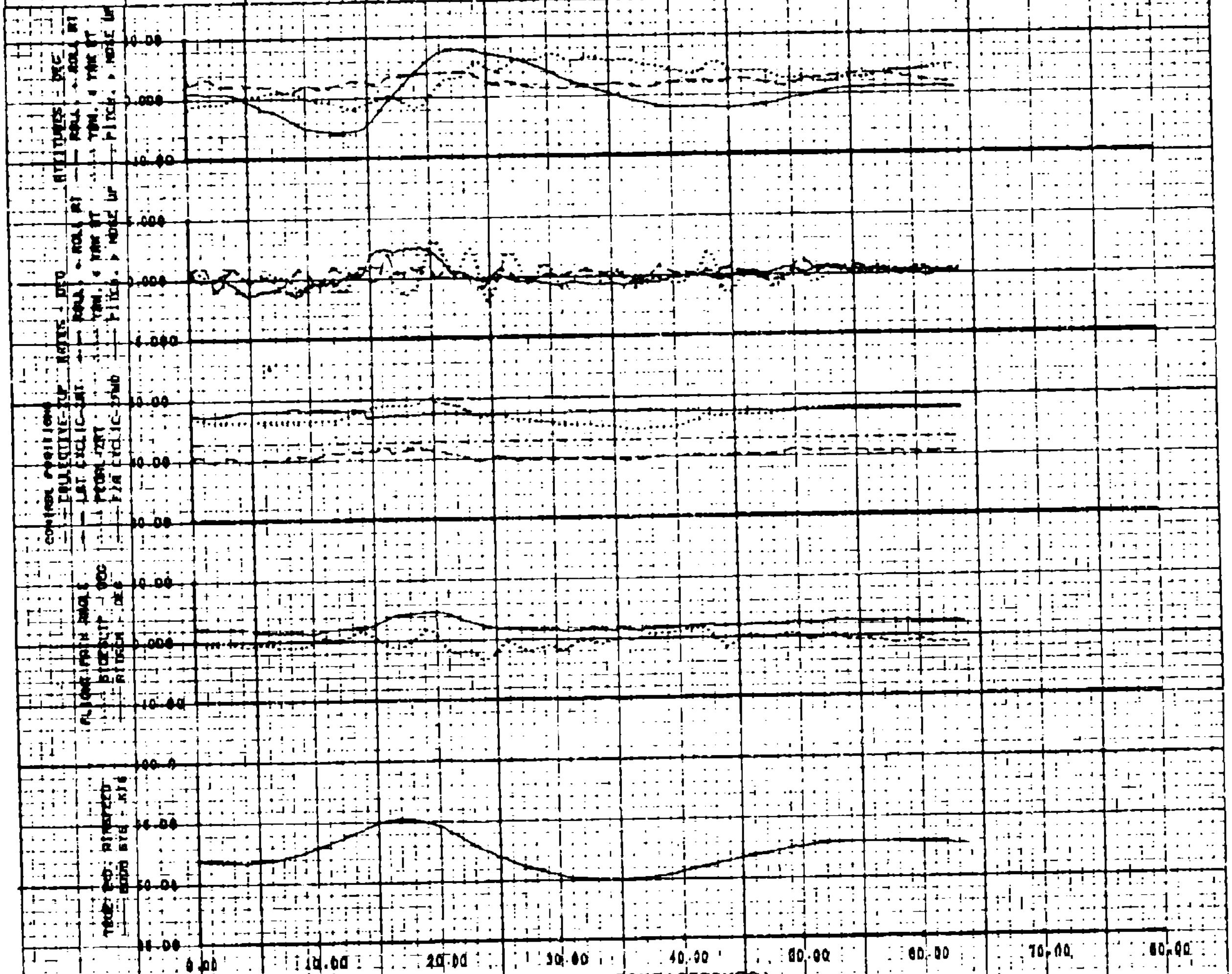


FIGURE 6
LONGITUDINAL LONG TERM RESPONSE
OH-58C USA S/N 69-16214

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	TRIM DENSITY ALTITUDE (FT)	AVG OAT (°C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KCAS)	CONFIGURATION	TRIM FLIGHT CONDITION	SCAS CONDITION
3020	109.8(MID)	0.2(RT)	3720	25	354	58	CLEAN: DOORS ON	LEVEL	OFF

NOTE: MAST MOUNTED SIGHT INSTALLED (DUMMY)



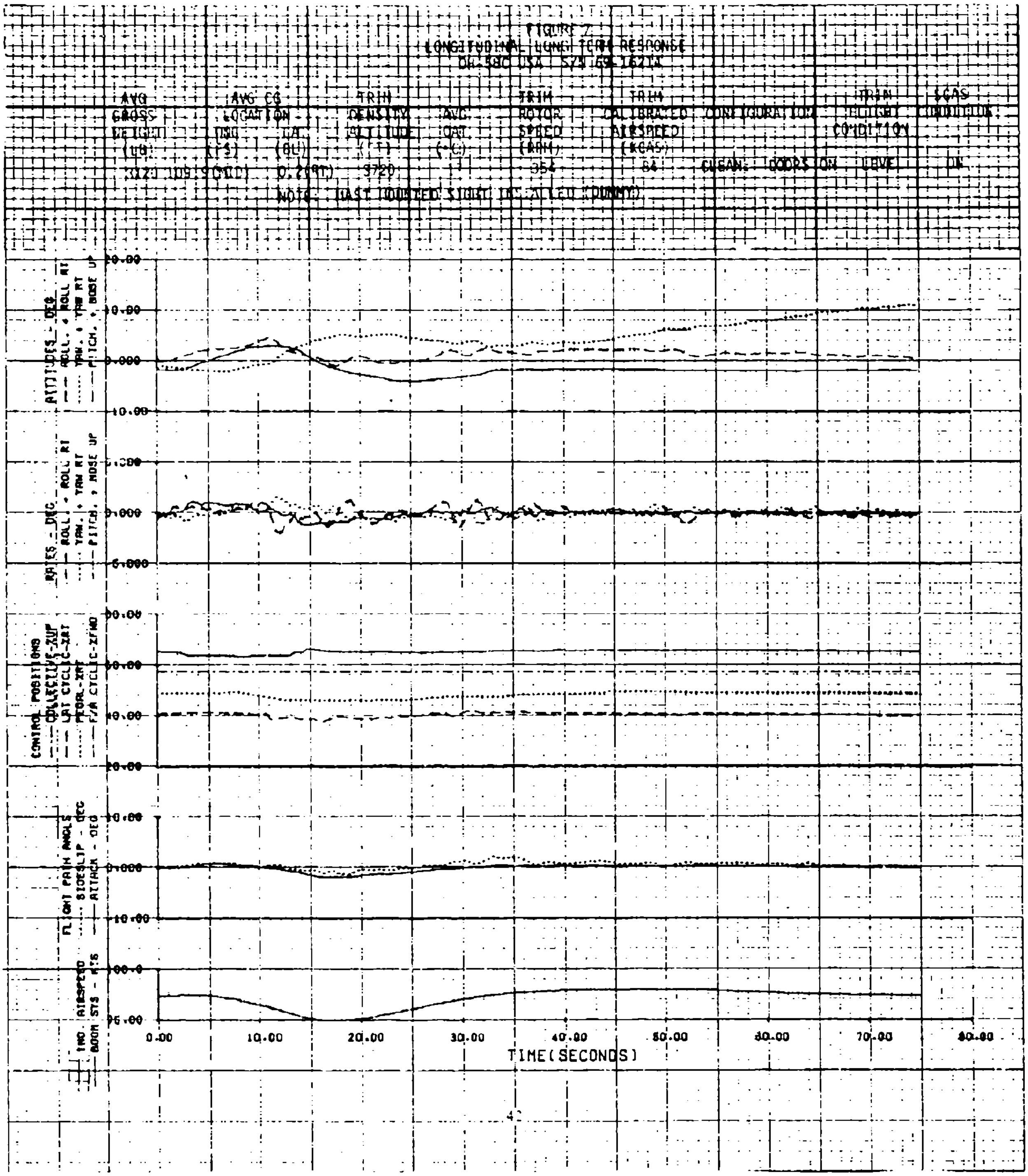
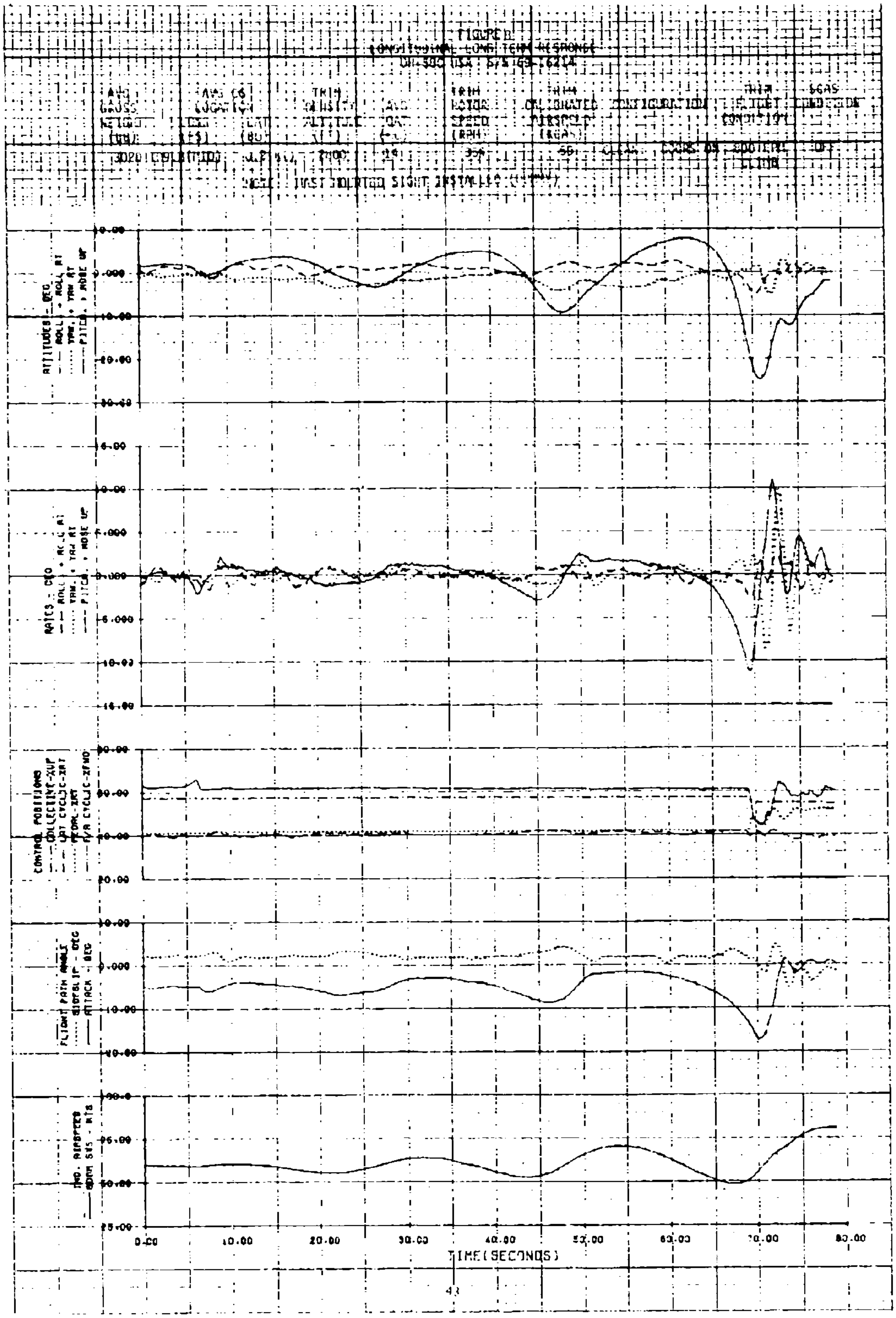
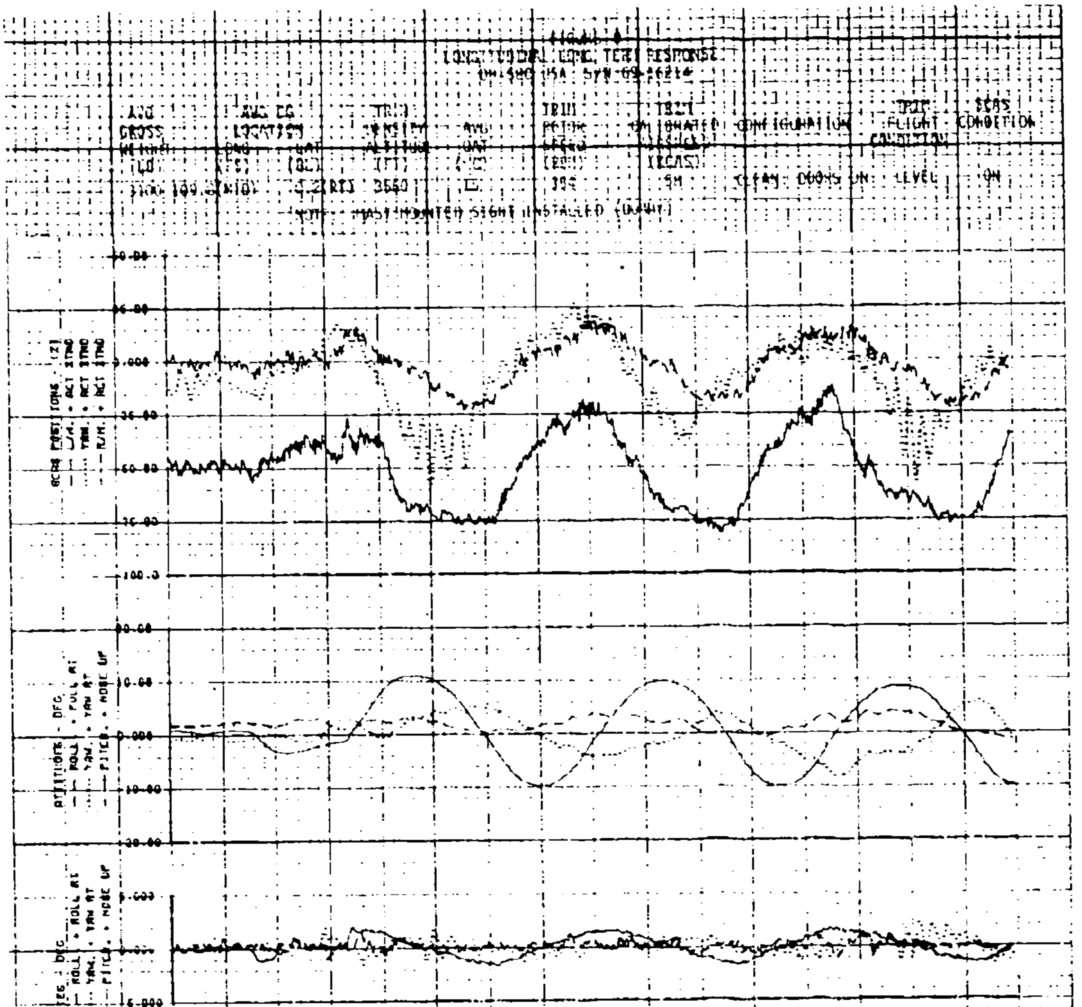


FIGURE 7
LONGITUDINAL LONG TERM RESPONSE
USA
AVG GROSS WEIGHT
AVG CG LOCATION
TRIM DENSITY ALTITUDE
AVG OAT
TRIM ROTOR SPEED
TRIM CALIBRATED AIRSPEED (KCAS)
CONFIGURATION
TRIM FLIGHT CONDITION
SCAS CONDITION
ATTITUDES - DEG
ROLL, + ROLL RT
YAW, + YAW RT
PITCH, + NOSE UP
RATES - DEG
CONTROL POSITIONS
COLLECTIVE
LAT CYCLIC
PEDAL
F/A CYCLIC
FLIGHT PATH ANGLES
SIDESLIP - DEG
ATTACK - DEG
AIRSPEED
BOOM STS - KTS
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
TIME(SECONDS)


LONGITUDINAL LONG TERM RESPONSE
AVG GROSS WEIGHT (LB)
AVG CG LOCATION
TRIM DENSITY ALTITUDE (FT)
AVG OAT
TRIM ROTOR SPEED (RPM)
TRIM CALIBRATED AIRSPEED (KCAS)
CONFIGURATION
TRIM FLIGHT CONDITION
SCAS CONDITION
ATTITUDES - DEG
RATES - DEG
CONTROL POSITIONS
FLIGHT PATH ANGLE
TIME (SECONDS)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00

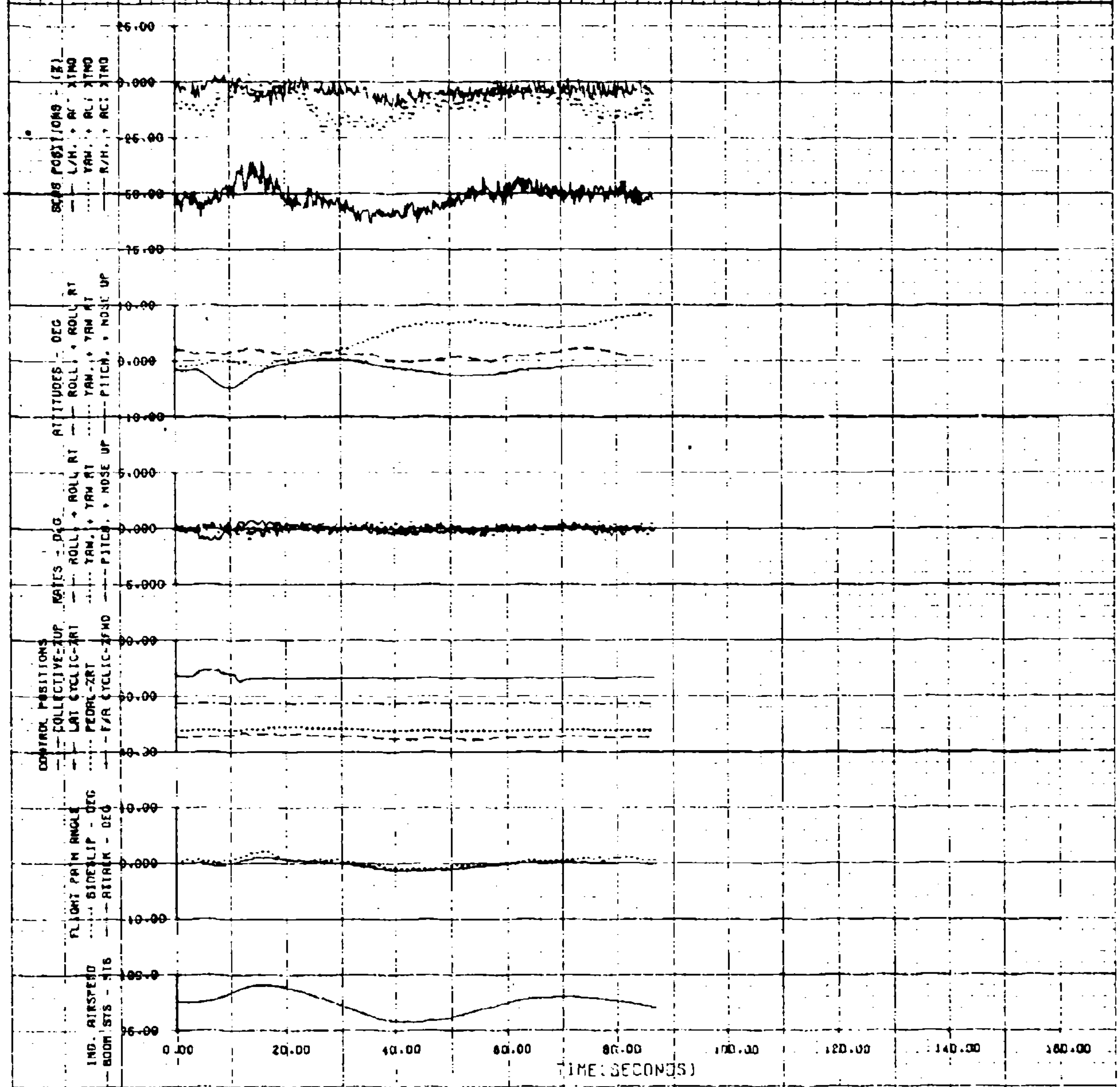


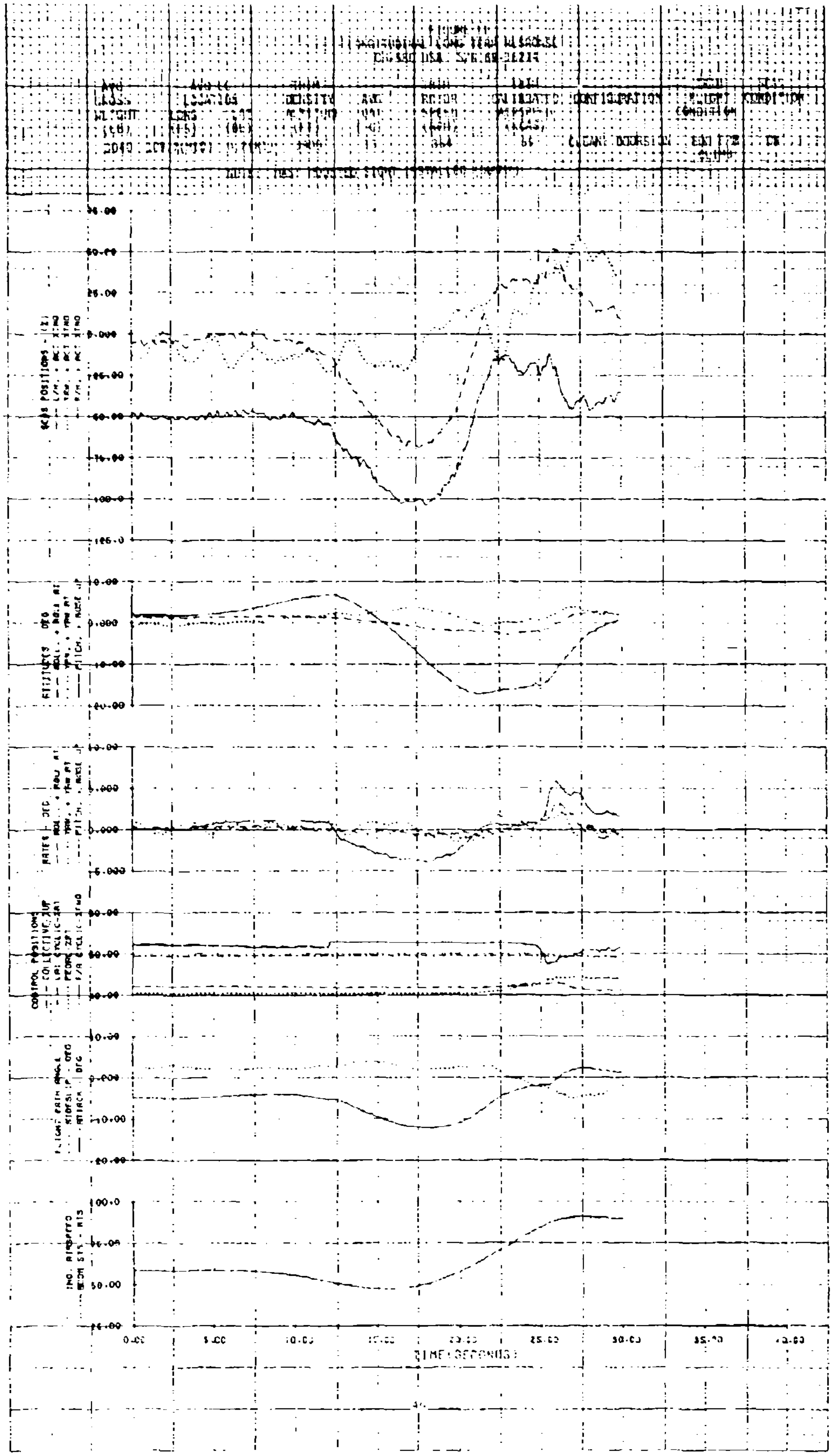
GROSS WEIGHT
CONFIGURATION
FLIGHT CONDITION
SCAS CONDITION
CLEAN: DOORS ON
LEVEL
ON
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
TIME(SECONDS)

FIGURE 19
LONGITUDINAL LONG TERM RESPONSE
OH-58C USA S/N 68-16212

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	TRIM DENSITY ALTITUDE (FT)	AVG OAT (°C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KCAS)	CONFIGURATION	TRIM FLIGHT CONDITION	SCAS CONDITION
3120	103.9(MID)	0.2(RT)	3660	17	354	54	CLEAN, DOORS ON	LEVEL	ON

NOTE: MAST MOUNTED SIGHT INSTALLED (DUMMY).





CONFIGURATION
CONDITION
TIME (SECONDS)

FIGURE 12A
LONGITUDINAL LONG TERM RESPONSE
OH-58C USA S/N 68-16219

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN)	AVG CG LOCATION LAT (IN)	TRIM DENSITY ALTITUDE (FT)	AVG OAT (°C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KCAS)	CONFIGURATION	TRIM FLIGHT CONDITION	SCAS CONDITION
[illegible]	[illegible]	0.2 (RT)	2120	[illegible]	354	50	CLEAN, DOORS ON	1500 FPM CLIMB	ON

NOTE: MAST MOUNTED SIGHT INSTALLED (DUMMY)

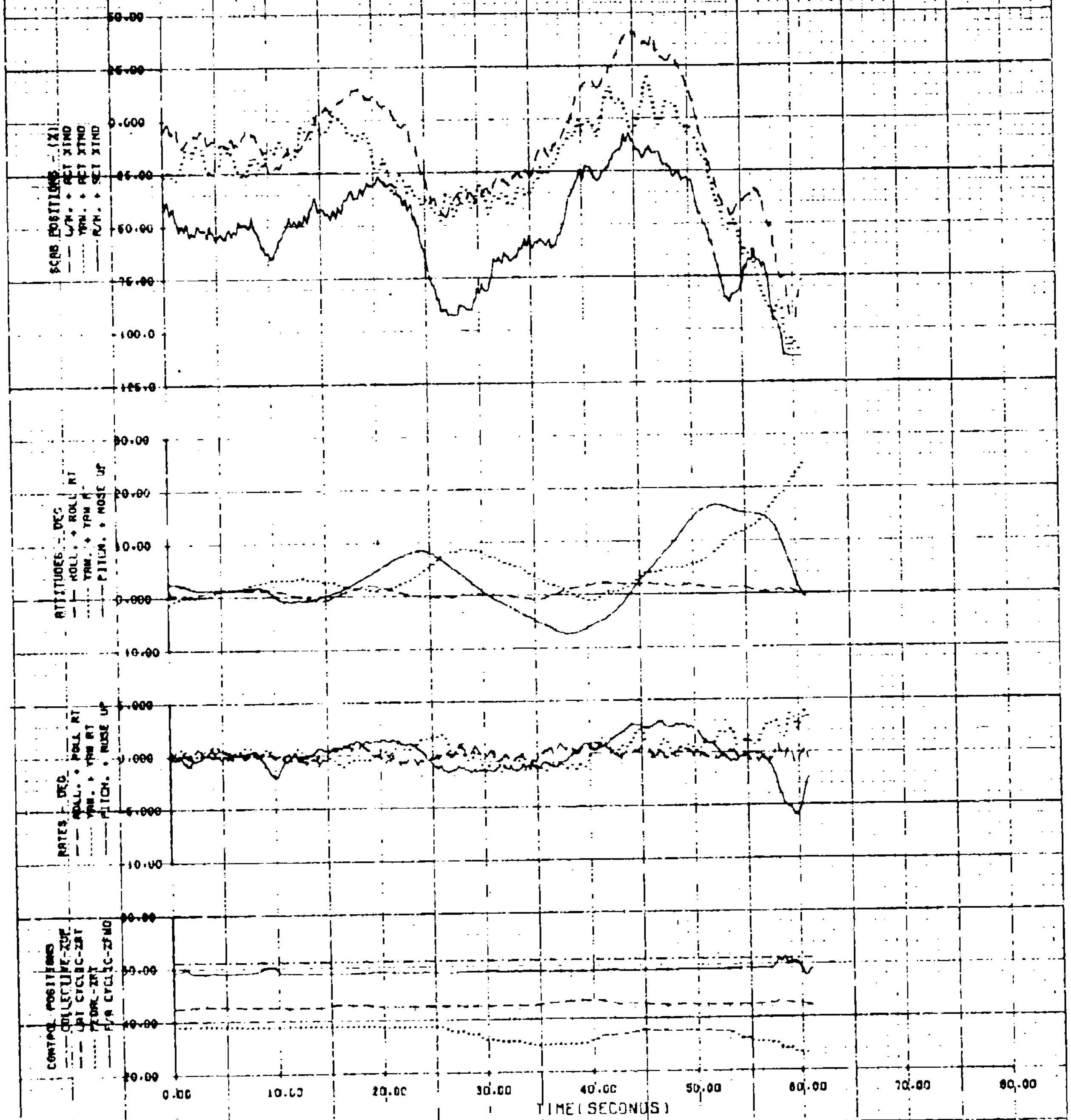
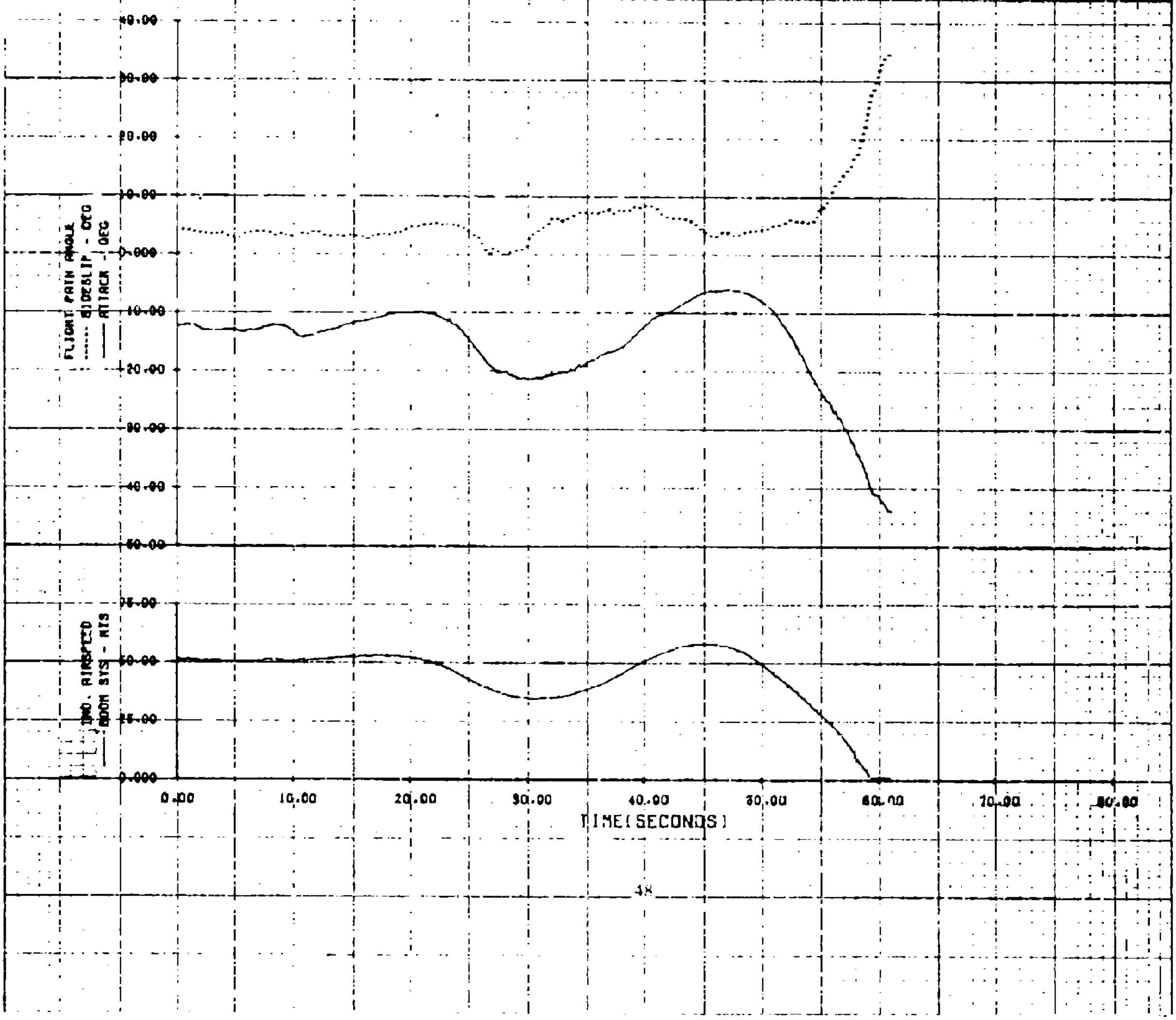


FIGURE 120
LONGITUDINAL LONG TERM RESPONSE
OH-58C USA S/N 69-16724

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	TRIM DENSITY ALTITUDE (FT)	AVG OAT (°C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KCAS)	CONFIGURATION	TRIM FLIGHT CONDITION	SCAS CONDITION
2960	109.2(MID)	0.2(RT)	2120	15.5	354	59	CLEAN; DOORS ON	CLIMB	ON

NOTE: MAST MOUNTED SIGHT INSTALLED (DUMMY)



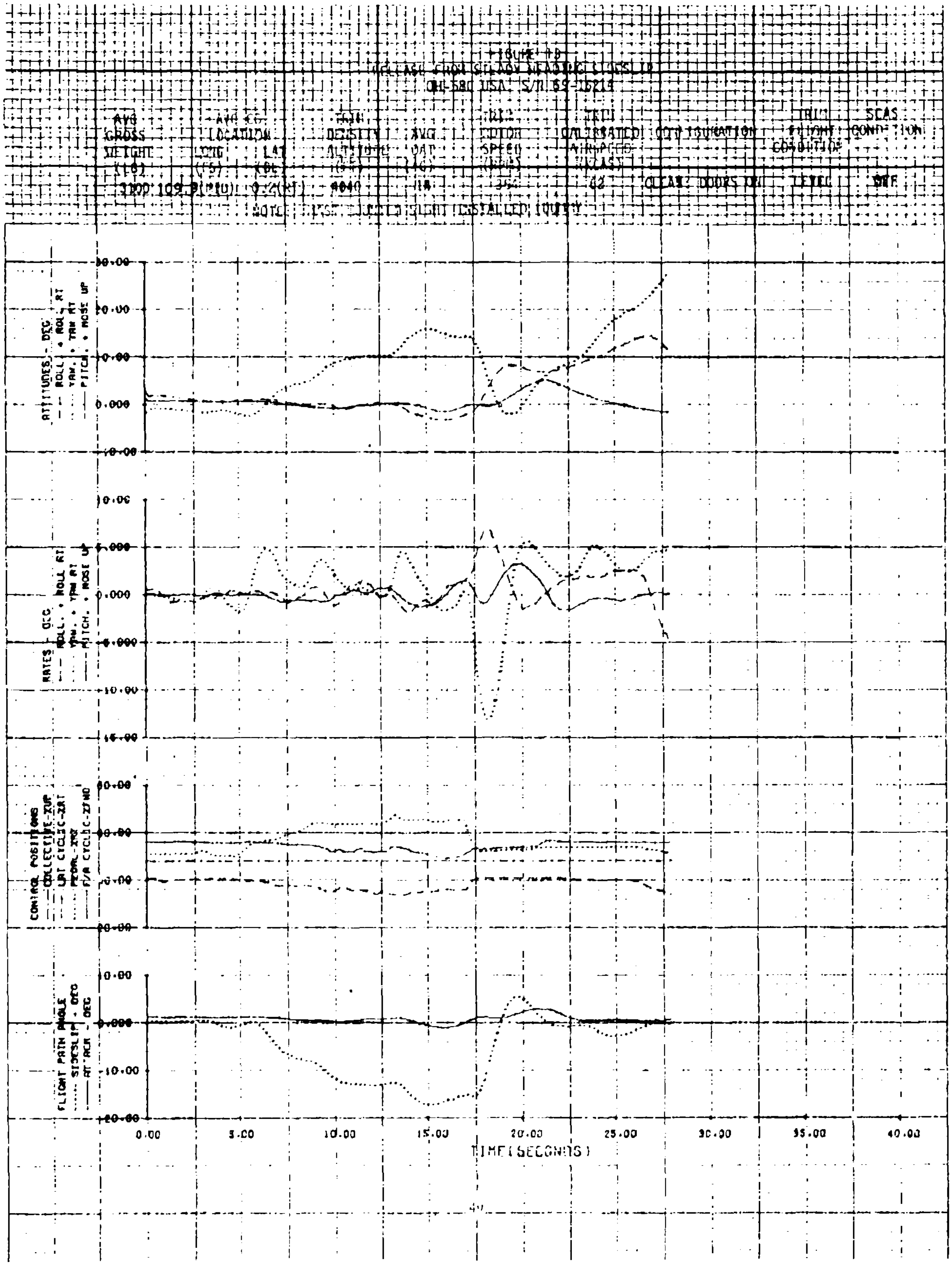


FIGURE 18
RELEASE FROM STEADY HEADING SIDESLIP
OH-58C USA S/N
AVG GROSS WEIGHT (LB)
AVG CG LOCATION LONG LAT
DENSITY ALTITUDE
AVG OAT
ROTOR SPEED
CALIBRATED AIRSPEED
CONFIGURATION
TRIM FLIGHT CONDITION
SCAS CONDITION
3100
4040
62
CLEAN; DOORS ON
LEVEL
OFF
ATTITUDES - DEG
ROLL, + ROLL RT
YAW, + YAW RT
PITCH, + NOSE UP
RATES - DEG
CONTROL POSITIONS
COLLECTIVE-%UP
LAT CYCLIC-%RT
PEDAL-%RT
F/A CYCLIC-%FWD
FLIGHT PATH ANGLE
SIDESLIP - DEG
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
TIME (SECONDS)

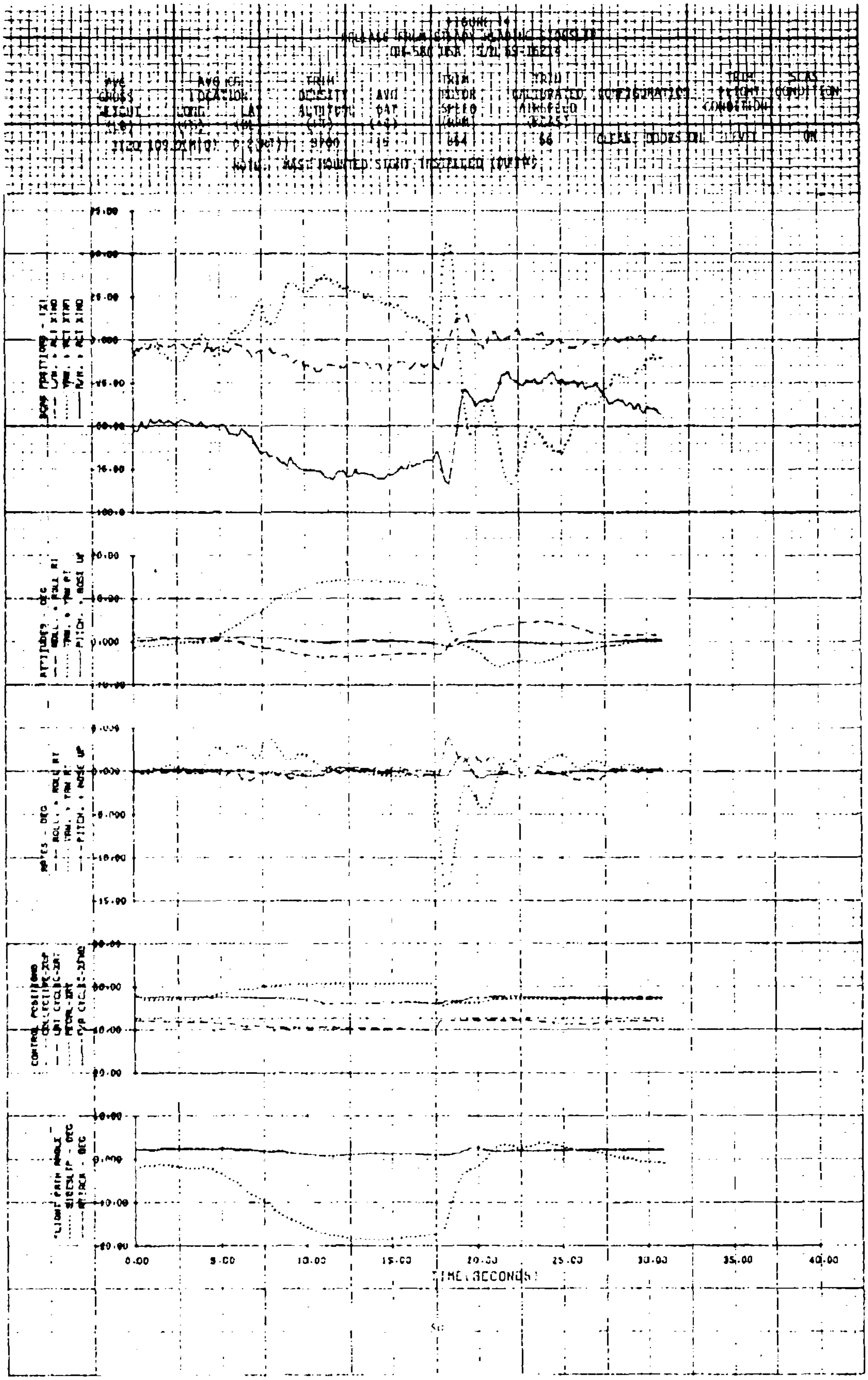


FIGURE 14
OH-58D USA S/N 85-16213
AVG GROSS WEIGHT (LB)
AVG CG LOCATION LONG (IN) LAT (IN)
TRIM DENSITY ALTITUDE (FT)
AVG OAT (°C)
TRIM ROTOR SPEED (RPM)
TRIM CALIBRATED AIRSPEED (KCAS)
CONFIGURATION
TRIM FLIGHT CONDITION
SCAS CONDITION
3120 109.2(MID) 0.2(RT) 5900 19 384 66 CLEAN, DOORS ON LEVEL ON
NOTE: MAST MOUNTED SIGHT INSTALLED (DUMMY)
TIME (SECONDS)
0.00 5.00 10.00 15.00 20.00 25.00 30.00 35.00 40.00

FIGURE 15
LATERAL CONTROL RESPONSE AND SENSITIVITY
OH-58C USA SN 69-16214

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	TRIM AIRSPEED (KCAS)	CONFIGURATION
3100	109.5(MID)	0.2(RT)	540	16.5	354	0.00315	HOVER	MAST MOUNTED SIGHT (DUMMY)

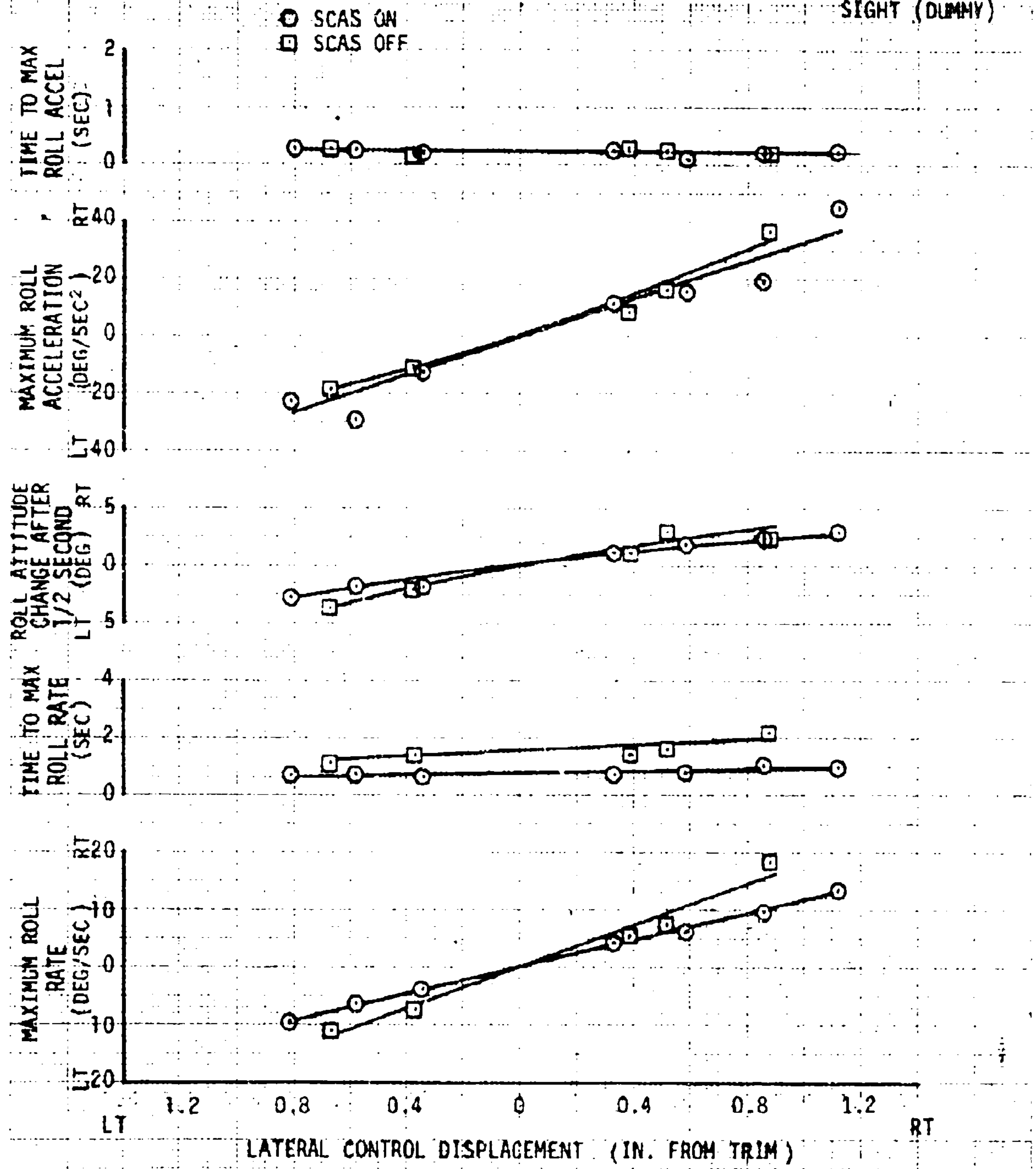


FIGURE 16
LONGITUDINAL CONTROL RESPONSE AND SENSITIVITY
OH-58C USA SN 69-16214

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	TRIM AIRSPEED (KCAS)	CONFIGURATION
3160	109.7(MID)	0.2(RT)	1320	22.5	354	0.00328	HOVER	MAST MOUNTED SIGHT (DUMMY)

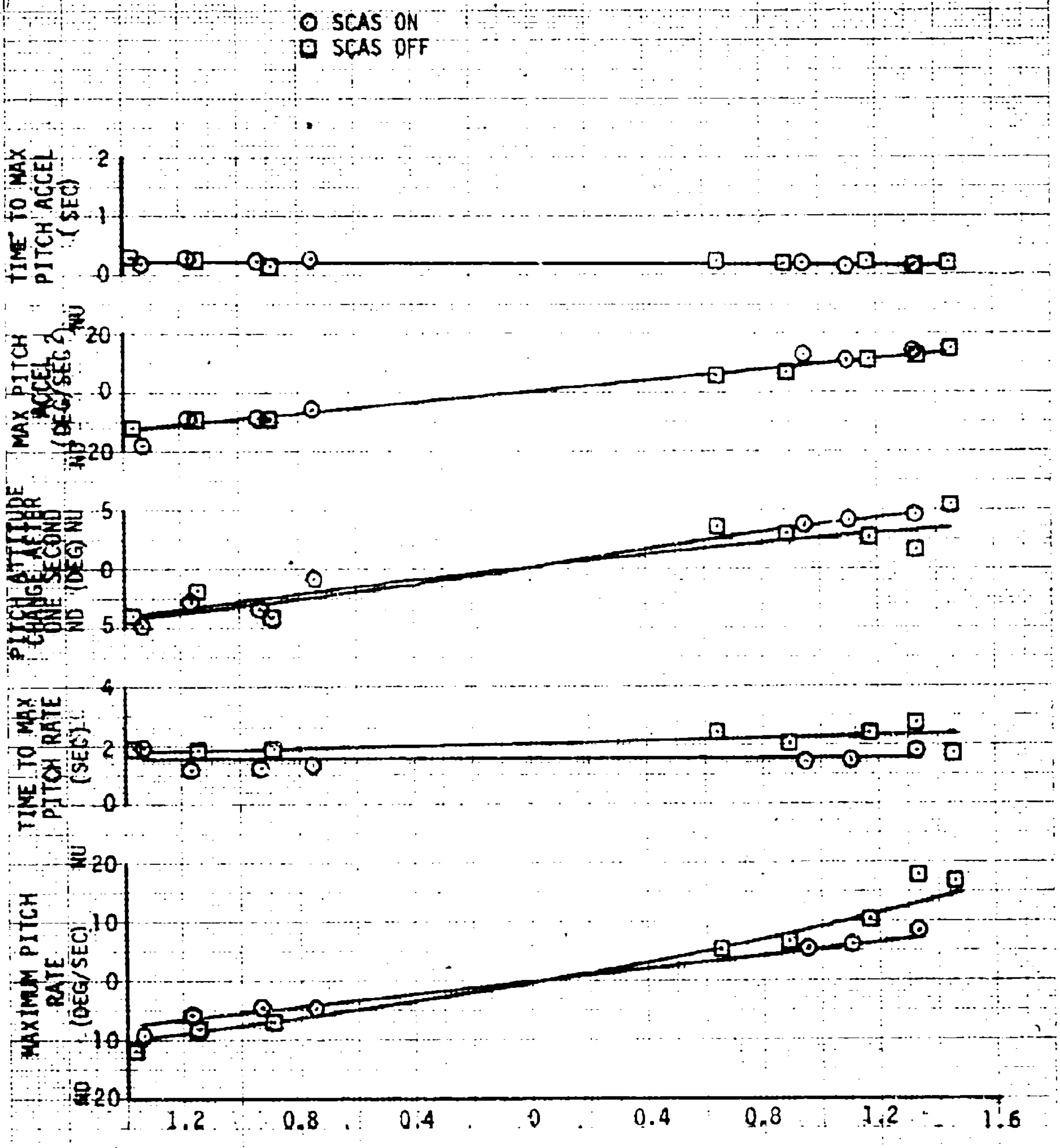


FIGURE 17
LATERAL CONTROL RESPONSE AND SENSITIVITY
OH-58C USA SN 69-16214

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	TRIM AIRSPEED (KCAS)	SCAS CONDITION
3080	109.4(MID)	0.3(RT)	4660	15.5	354	0.00354	86	ON

NOTES: 1. MAST MOUNTED SIGHT CONFIGURATION (DUMMY)

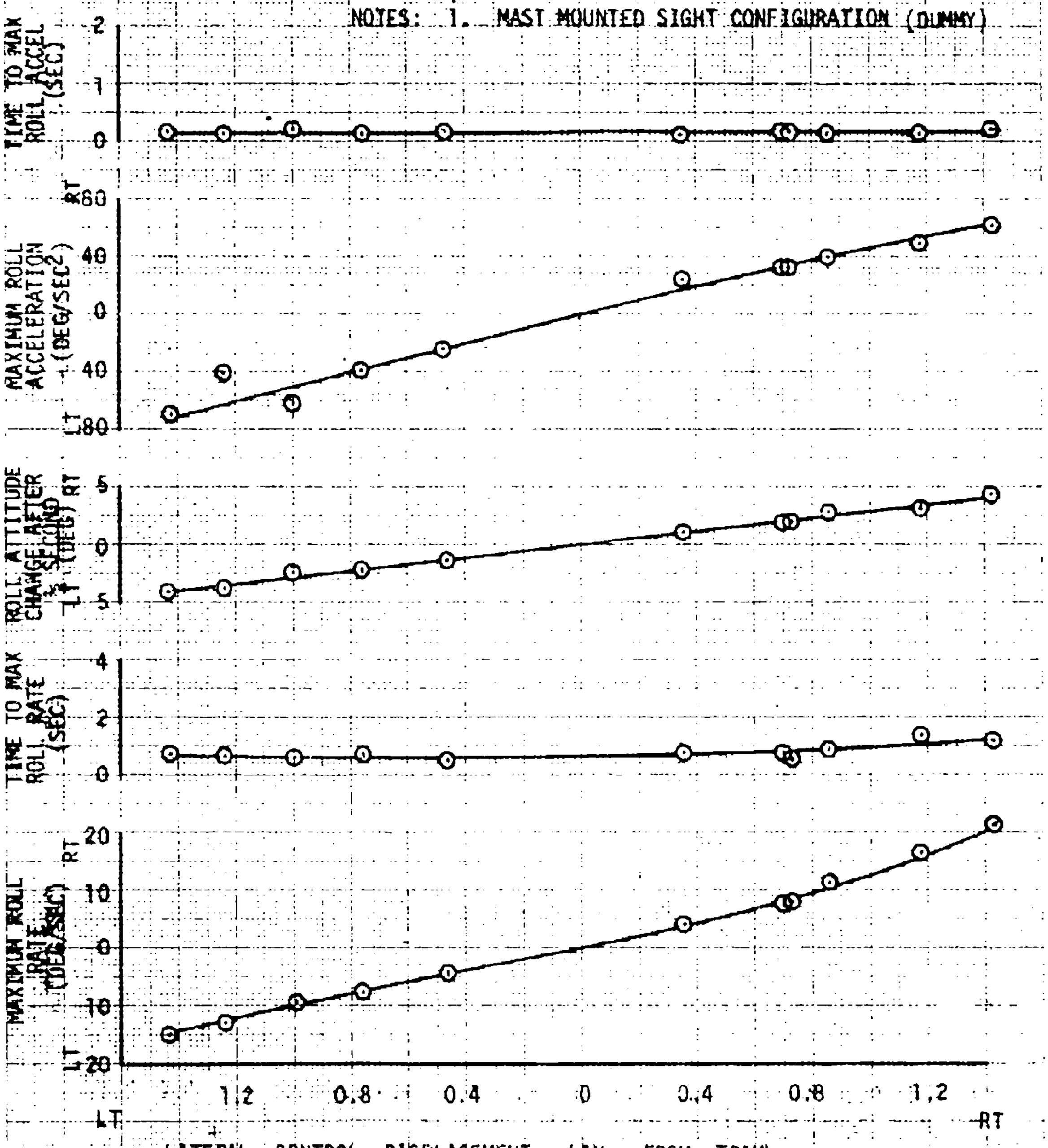
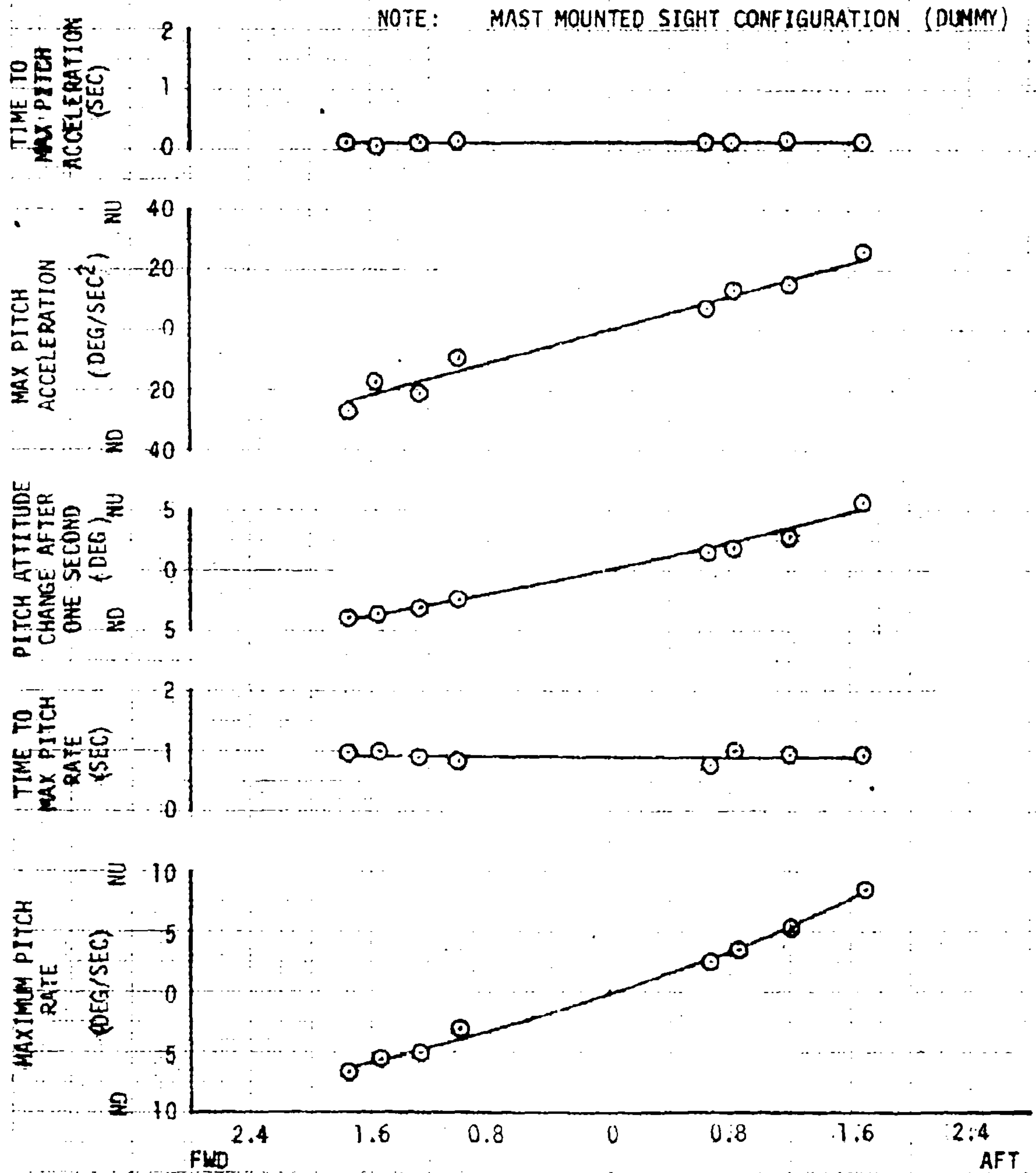


FIGURE 18
LONGITUDINAL CONTROL RESPONSE AND SENSITIVITY
OH-58C USA SN 69-16214

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	TRIM AIRSPEED (KCAS)	SCAS CONDITION
3140	109.5(MID)	0.3(RT)	5120	15.0	354	0.00366	85	ON

NOTE: MAST MOUNTED SIGHT CONFIGURATION (DUMMY)



LONGITUDINAL CONTROL DISPLACEMENT (IN. FROM TRIM)

FIGURE 19
LOW-SPEED FORWARD AND REARWARD FLIGHT
OH-58 C USA S/N 69-16214

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALT (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	SKID HEIGHT (FT)	SCAS CONDITION
○	3200	109.5(MID)	0.2(RT)	860	16.5	354	0.00327	25	ON
□	3220	109.6(MID)	0.2(RT)	2180	28.0	354	0.00342	25	ON

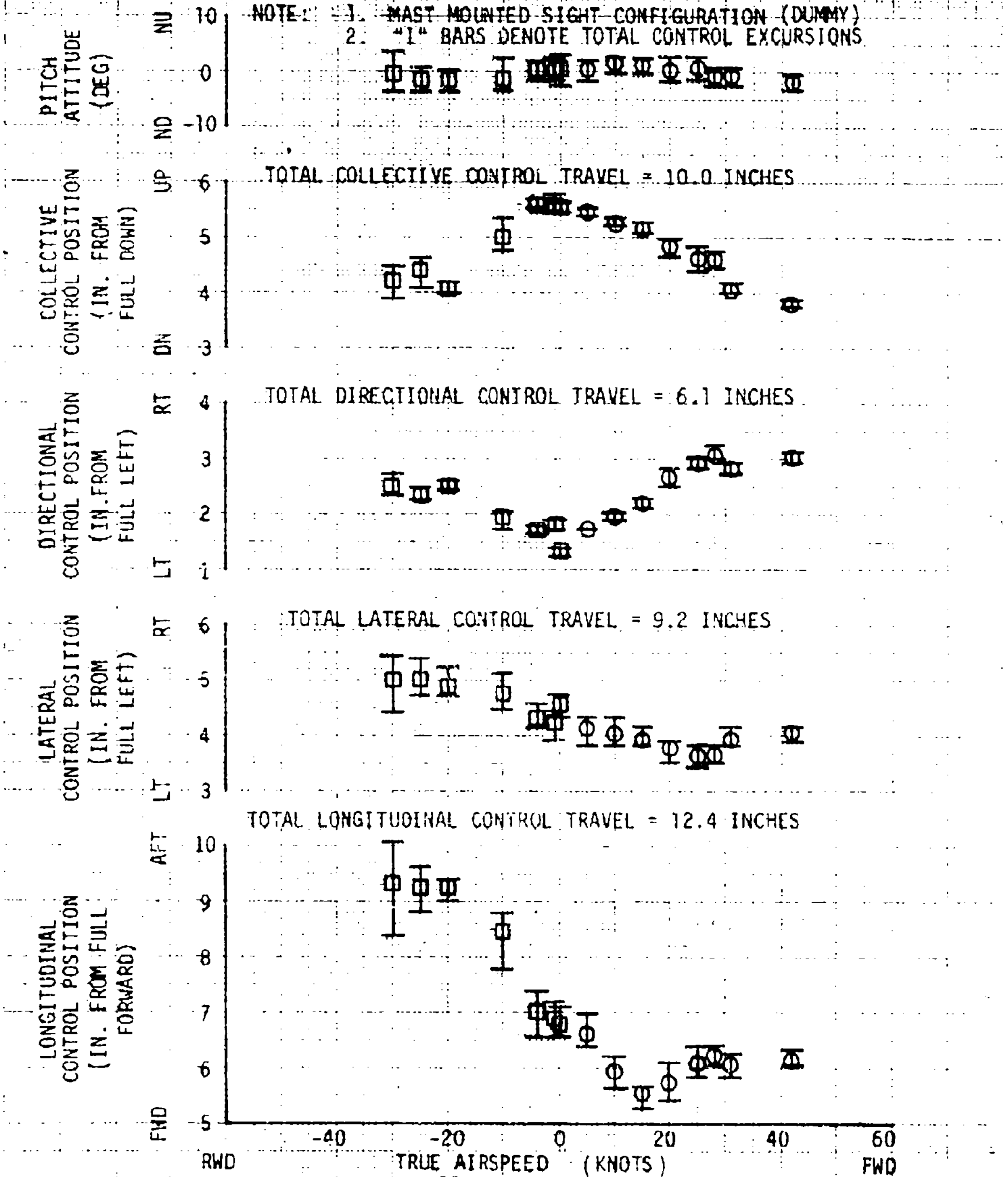


FIGURE 20
LOW-SPEED REARWARD FLIGHT
OH-58C USA S/N 69-16214

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALT (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	SKID HEIGHT (FT)	SCAS CONDITION
3180	109.4(MID)	0.2(RT)	2300	29.0	354	0.00340	25	OFF

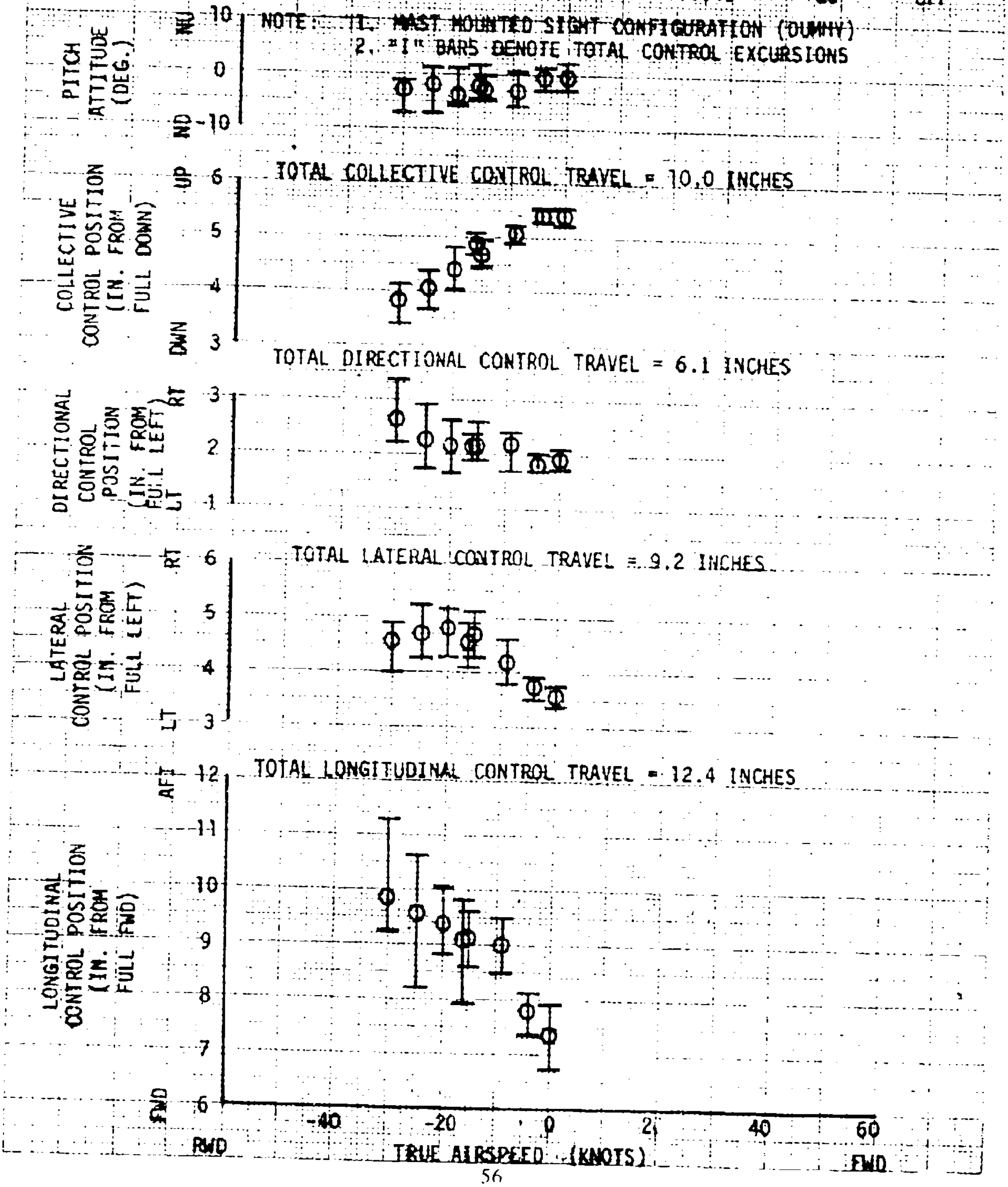


FIGURE 21
SIDEWARD FLIGHT
OH-58C USA S/N 69-16214

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALT (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	SKID HEIGHT (FT)	SCAS CONDITION
3080	109.2(MID)	0.2(MID)	2180	28.0	354	0.00329	25	OFF

NOTE: 1. MAST MOUNTED SIGHT CONFIGURATION (DUMMY)
2. "I" BARS DENOTE TOTAL CONTROL TRAVEL

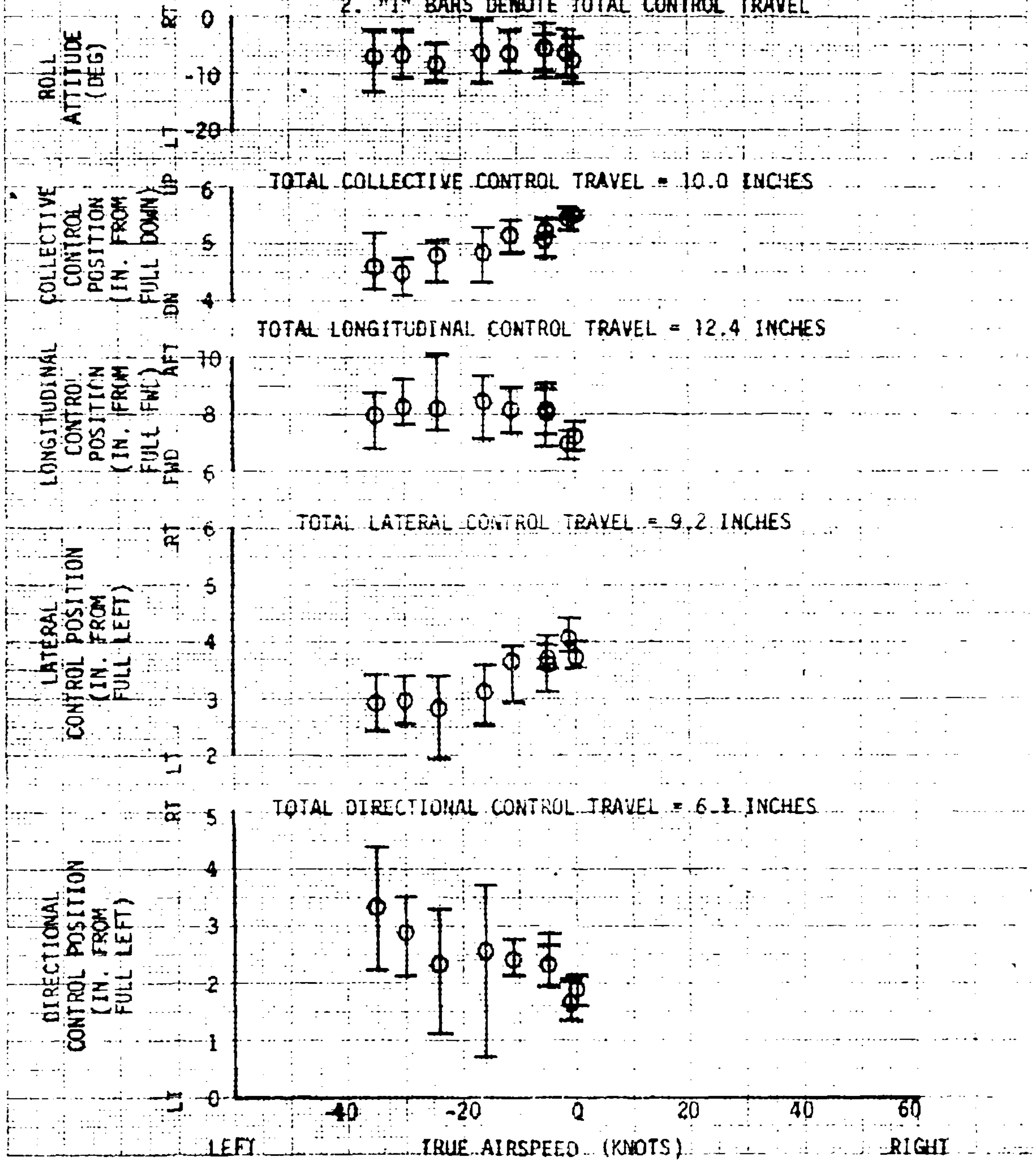
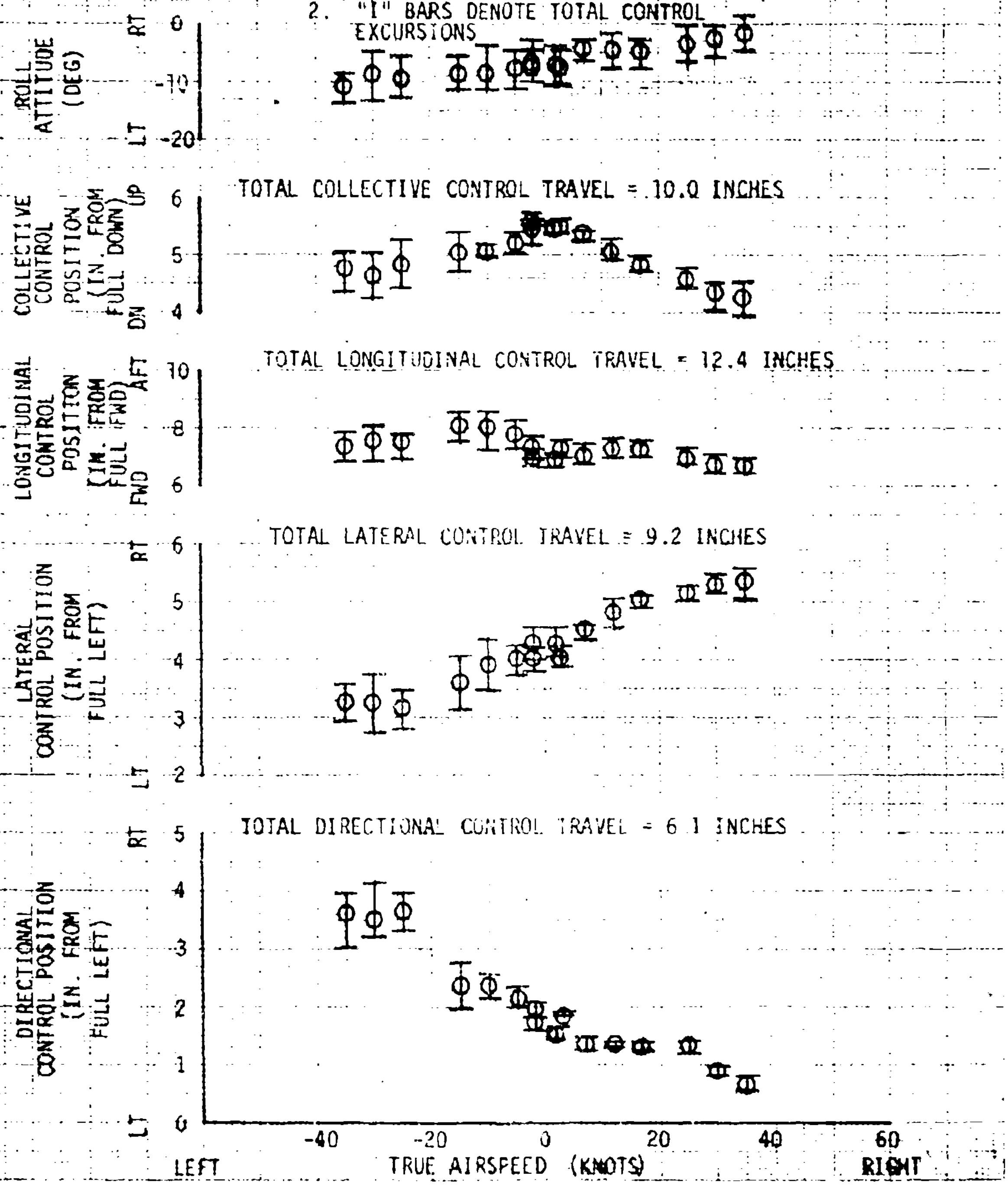


FIGURE 22
SIDEWARD FLIGHT
OH-58 C USA S/N 69-16214

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALT (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	SKID HEIGHT (FT)	SCAS CONDITION
3140	109.3(MID)	0.2(RT)	2180	28.0	354	0.00334	25	ON

1. MAST MOUNTED SIGHT CONFIGURATION (DUMMY)
2. "I" BARS DENOTE TOTAL CONTROL EXCURSIONS



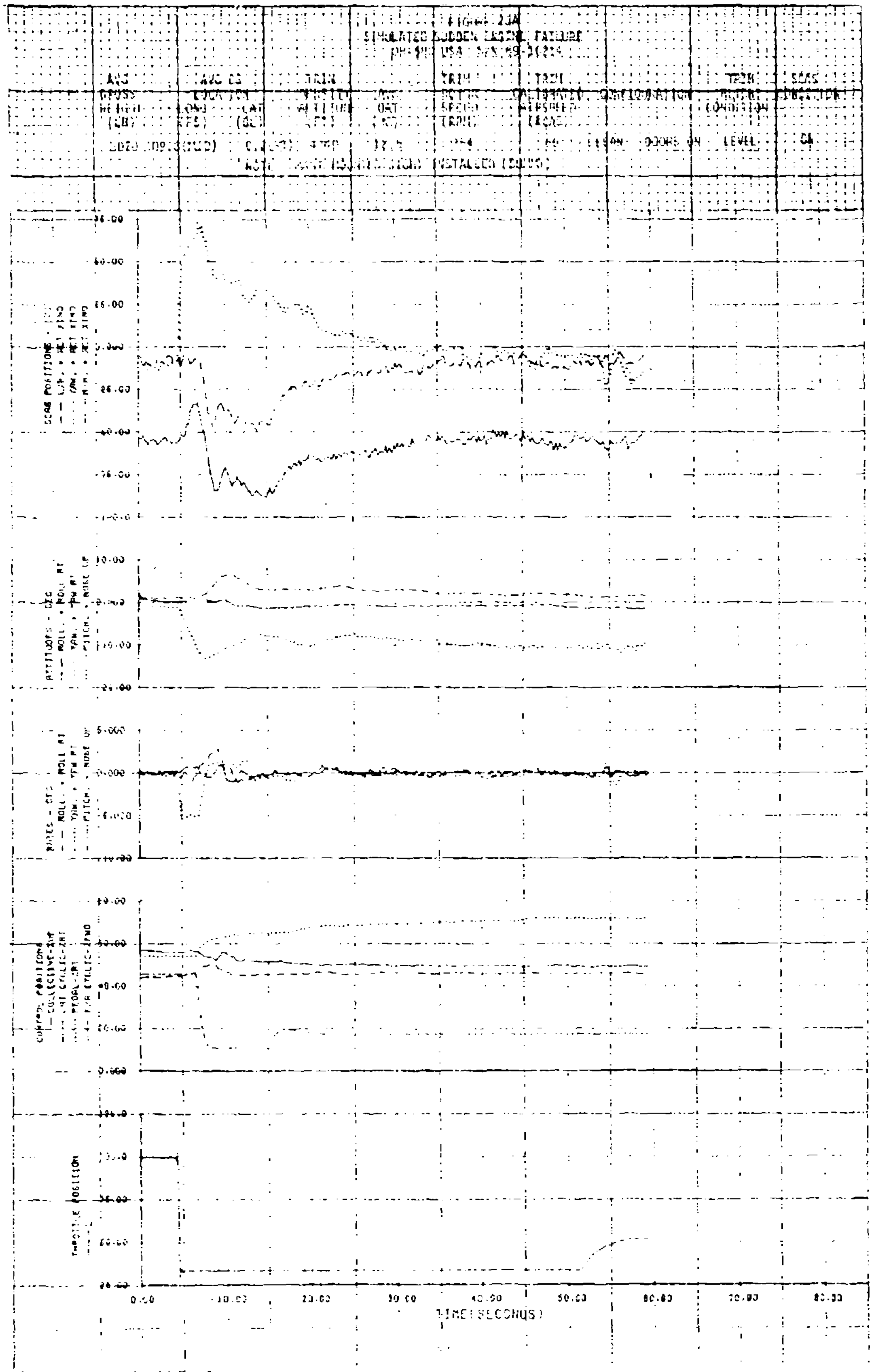


FIGURE 23A
SIMULATED SUDDEN ENGINE FAILURE
AVG GROSS WEIGHT (LB)
AVG CG LOCATION LONG (FS) LAT (BL)
TRIM ALTITUDE
TRIM ROTOR SPEED (RPM)
TRIM CALIBRATED AIRSPEED
CONFIGURATION
TRIM FLIGHT CONDITION
SCAS CONDITION
LEVEL
TIME (SECONDS)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
THROTTLE POSITION
CONTROL POSITIONS
ATTITUDES - DEG
RATES
SCAS POSITIONS

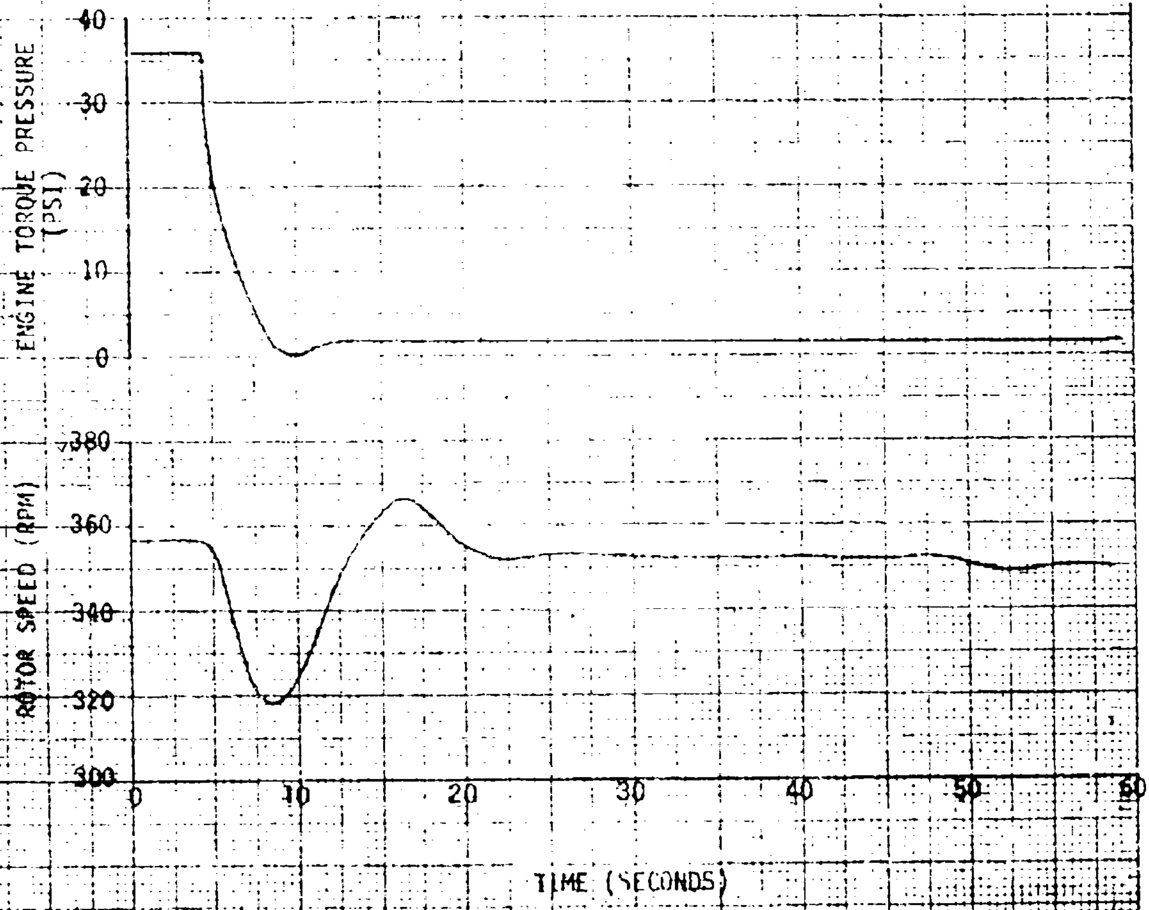
FIGURE 23[illegible]

SIMULATED SUDDEN ENGINE FAILURE

OH-58C USA S/N 69-16214

AVG GROSS WEIGHT (LB)	AVG LOCATION LONG (FS)	AVG LOCATION LAT (BL)	TRIM DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KCAS)	CONFIGURATION	TRIM FLT COND
3020	109.8MID	0.2RT	4340	12.5	354	60	CLEAN: DOORS ON	LEVEL ON

NOTE: MAST MOUNTED SIGHT INSTALLED (DUMMY)



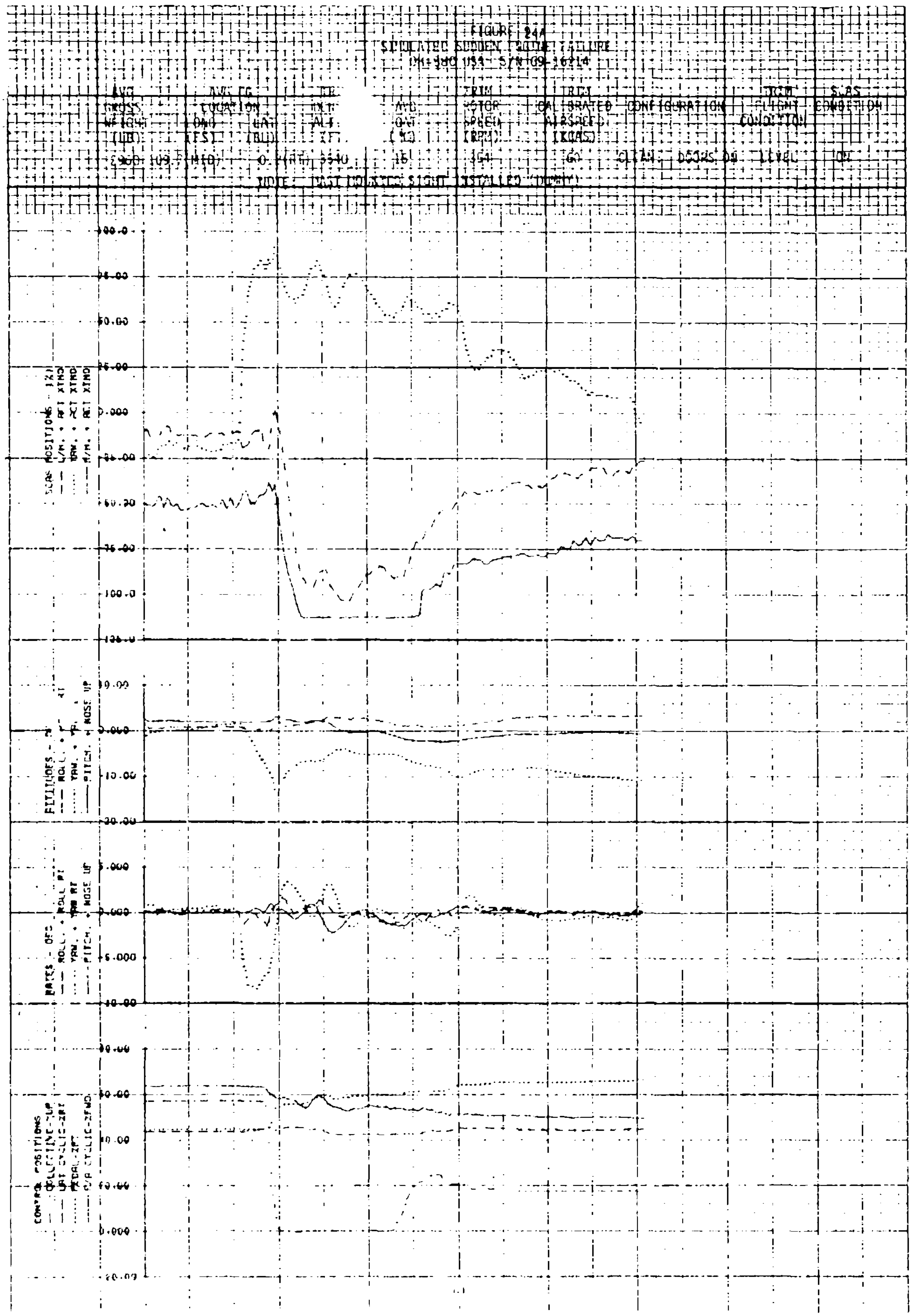


FIGURE 24A
CALIBRATED
CONFIGURATION
CONDITION
100.0
50.00
0.000
100.0
10.00
0.000
-10.00
-20.00
5.000
0.000
-5.000
-10.00
0.000

FIGURE [illegible]
SIMULATED SUDDEN ENGINE FAILURE
OH-58C USA S/N 69-16424

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	TRIM DENSITY ALTITUDE (FT)	AVG OAT (°C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KCAS)	CONFIGURATION	TRIM FLIGHT CONDITION	SCAS CONDITION
2960	109.[illegible](MID)	0.[illegible]([illegible])	[illegible]640	[illegible]	354	60	CLEAN, DOORS ON	CLIMB	ON

NOTE: MAST MOUNTED SIGHT INSTALLED (DUMMY)

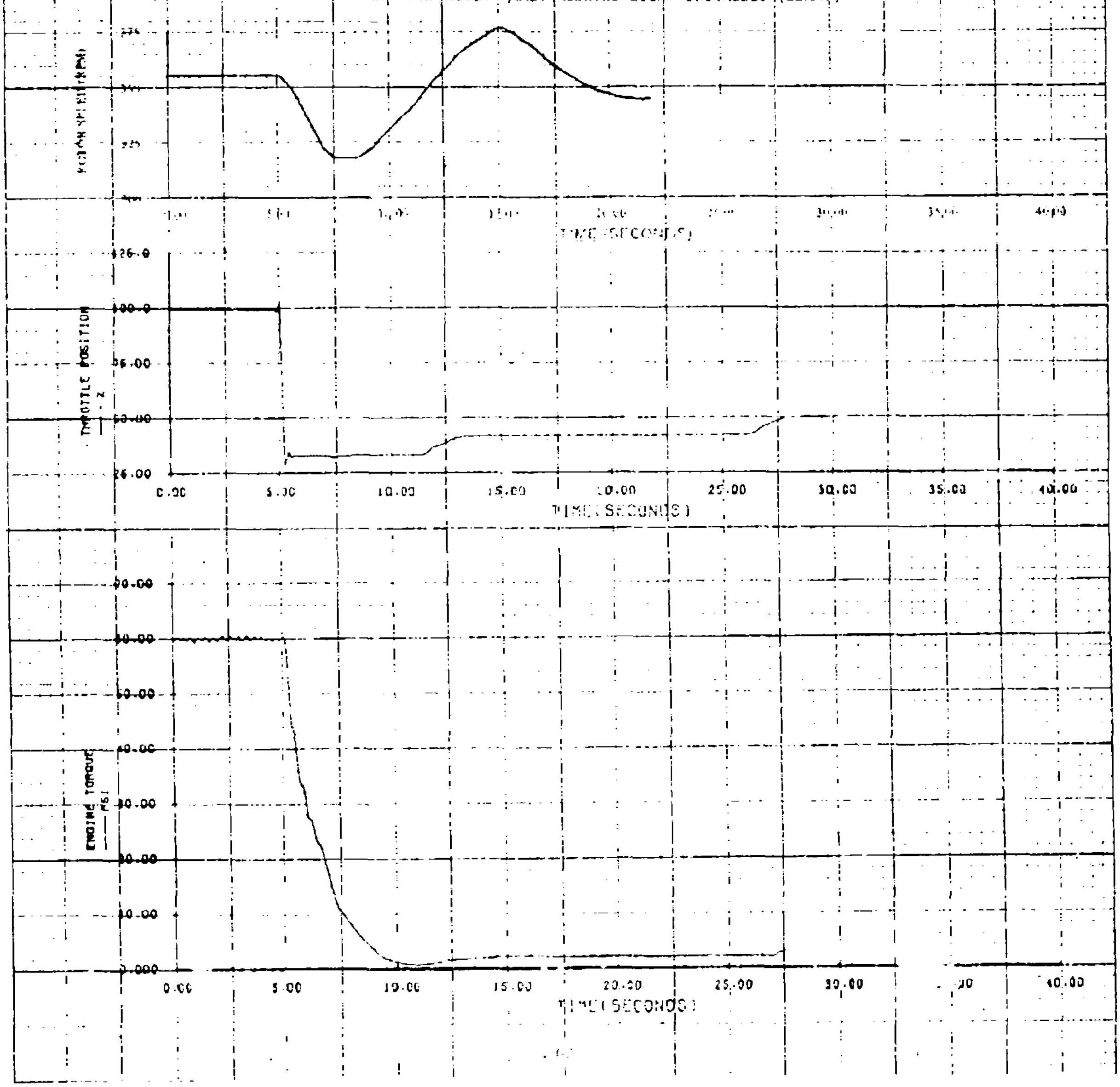
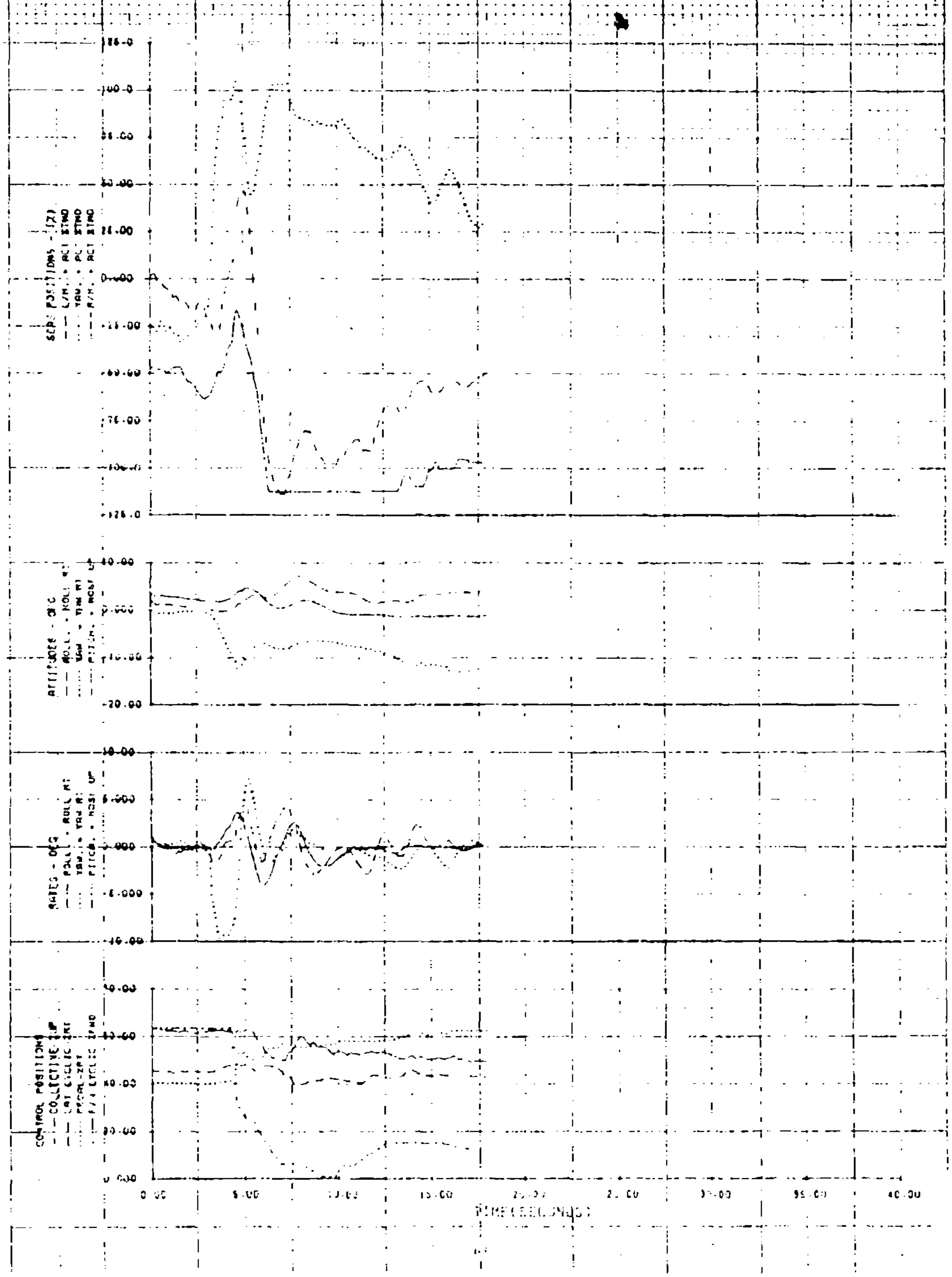
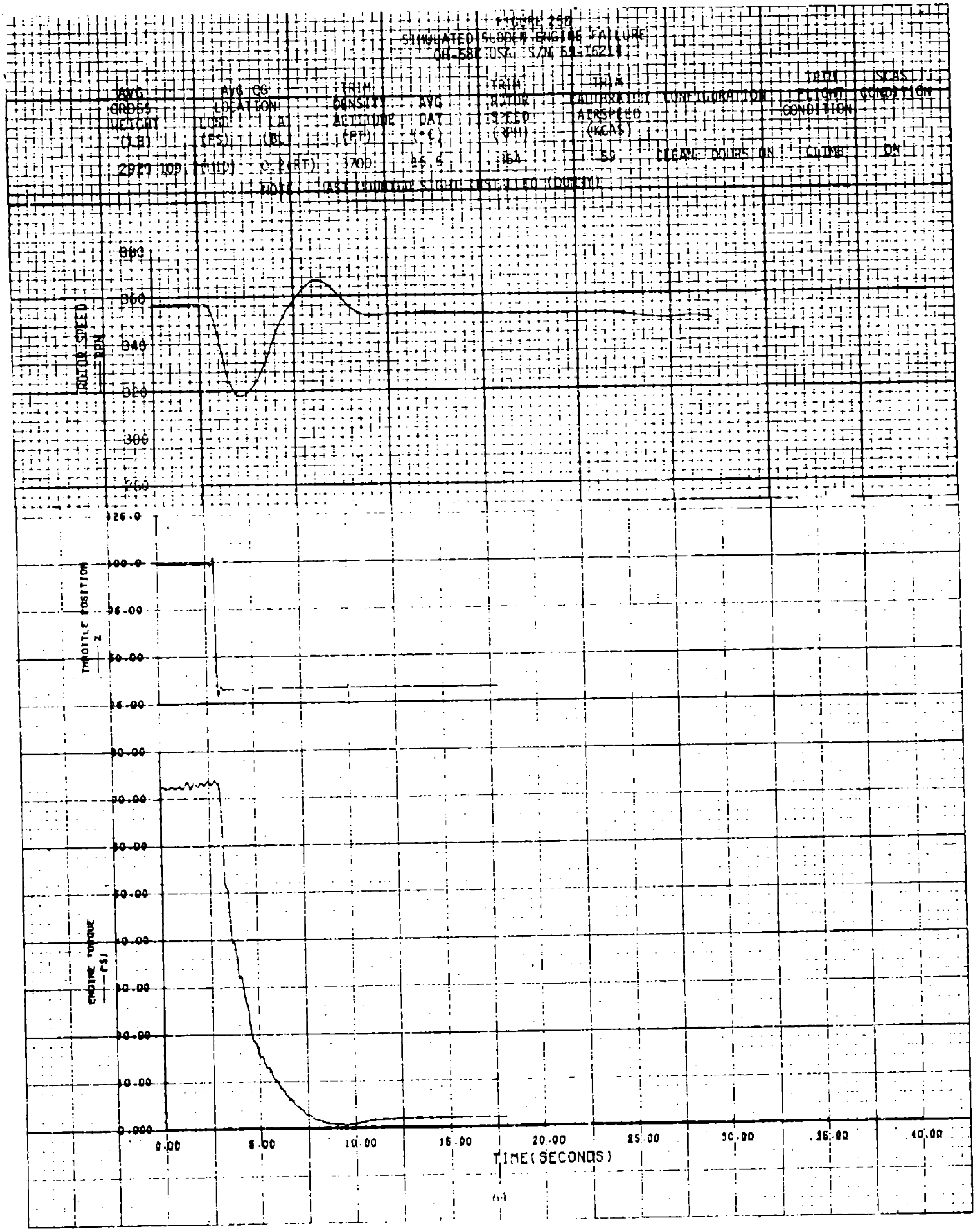


FIGURE 2[illegible]

SIMULATED SUDDEN ENGINE FAILURE





SIMULATED SUDDEN ENGINE FAILURE
AVG GROSS WEIGHT (LB)
AVG CG LOCATION
TRIM DENSITY ALTITUDE (FT)
AVG OAT
TRIM ROTOR SPEED (RPM)
CALIBRATED AIRSPEED (KCAS)
CONFIGURATION
TRIM FLIGHT CONDITION
SCAS CONDITION
CLIMB
ON
ROTOR SPEED RPM
THROTTLE POSITION %
ENGINE TORQUE PSI
TIME (SECONDS)

FIGURE 26
SCAS DISENGAGEMENT
OH-58C USA S/N 69-16214

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	TRIM DENSITY ALTITUDE (FT)	AVG OAT (°C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KCAS)	CONFIGURATION	TRIM FLIGHT CONDITION	SCAS CONDITION
3320	10[illegible].5(AFT)	0.2(RT)	3820	15	354	60	CLEAN: DOORS OFF	LEVEL	[illegible]

NOTE: MAST MOUNTED SIGHT INSTALLED (DUMMY)

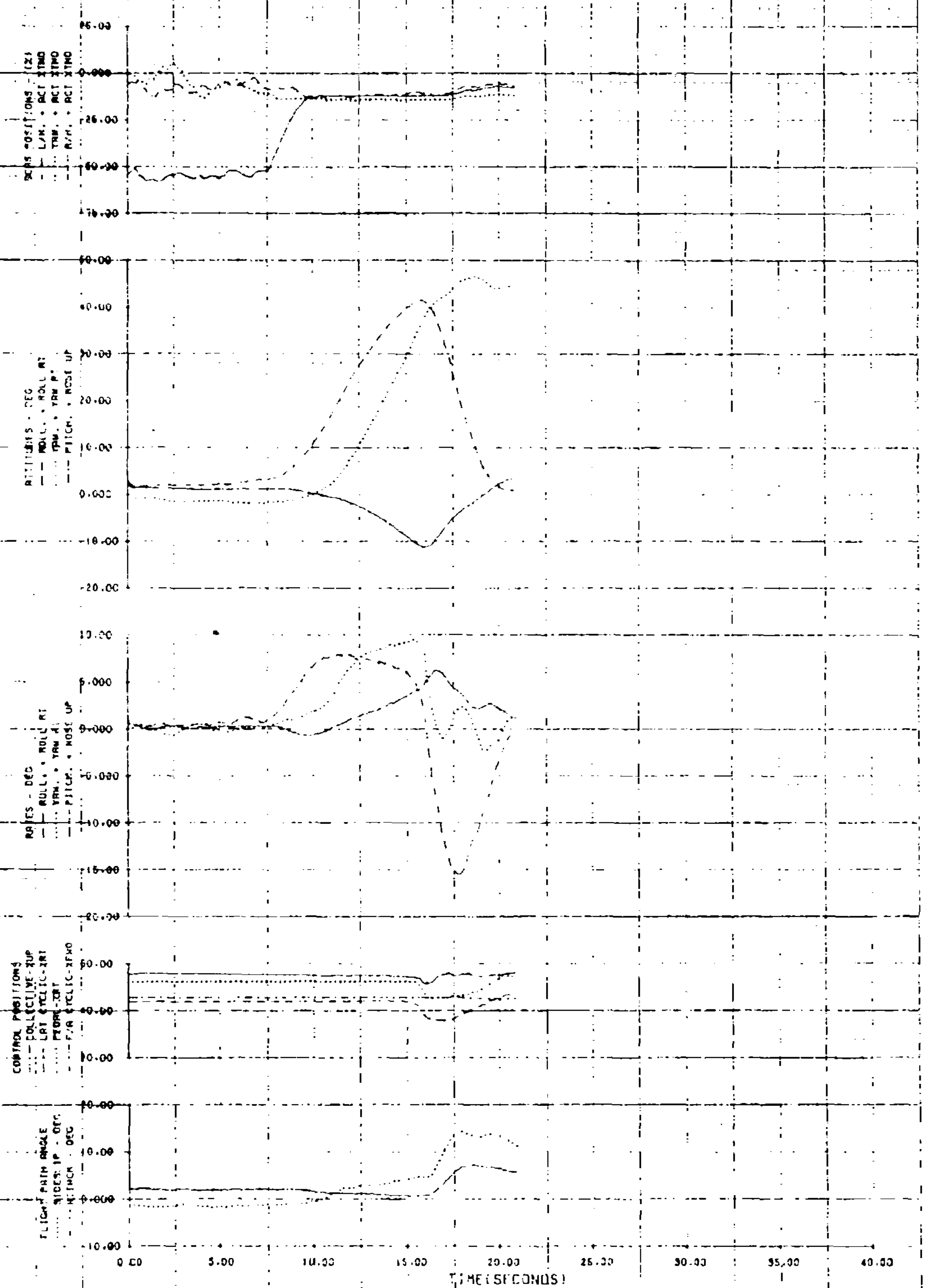
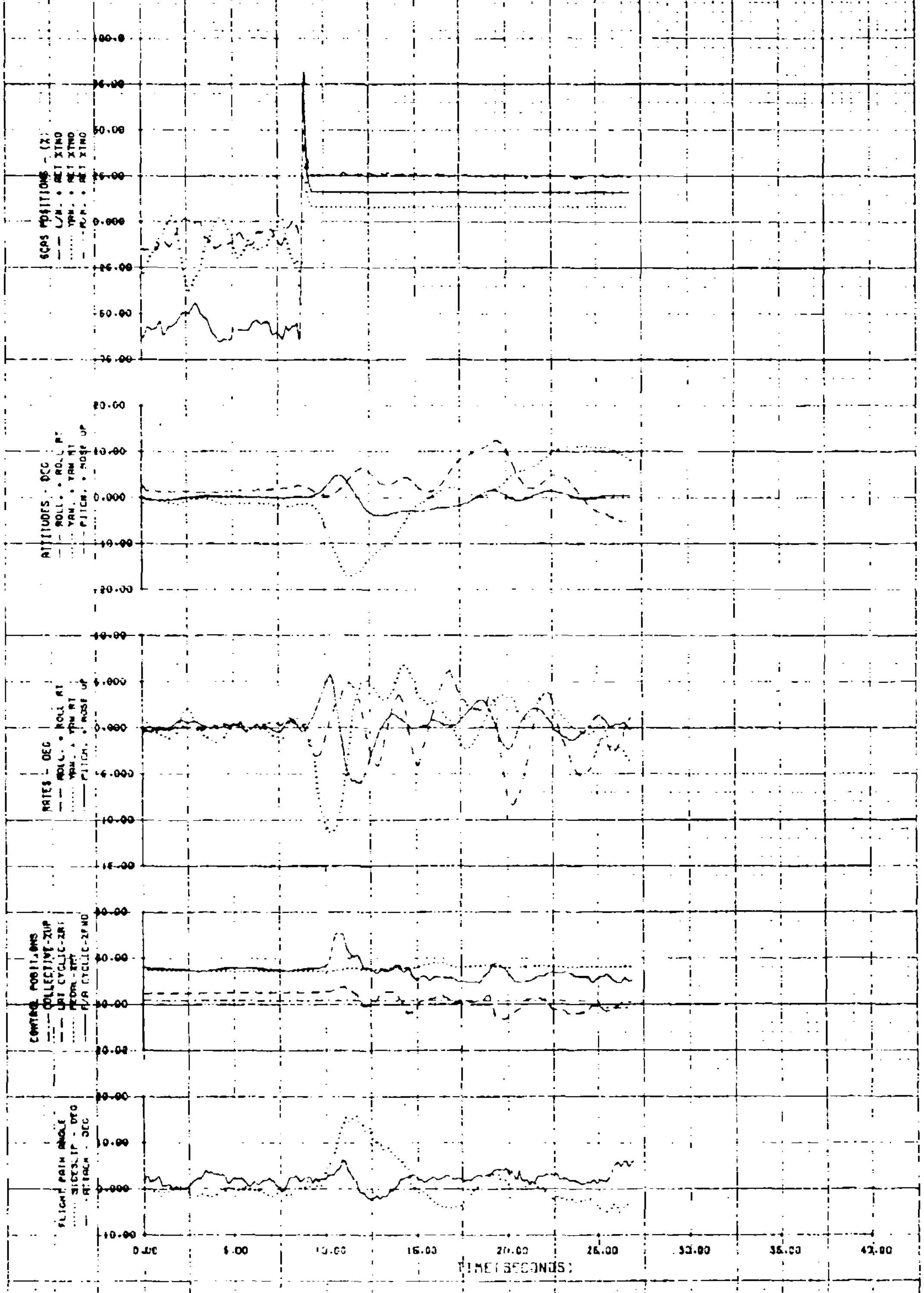


FIGURE 27
SCAS INVERTER FAILURE
OH-58C USA S/N 69-16214

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	TRIM DENSITY ALTITUDE (FT)	AVG OAT (°C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KCAS)	CONFIGURATION	TRIM FLIGHT CONDITION
3020	109.8(MID)	0.2(RT)	3820	15	354	60	CLEAN, DOORS ON	LEVEL

NOTE: MAST MOUNTED SIGHT INSTALLED (DUMMY).



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